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CORRECTIONS

Volume 64, September 1936, page 312, *East Gulf States*, temperature departure, "5.3", should be "3.5".

October 1936, page 333, table 8: In columns 7, 8, 10, and 11, the headings, I_m, I_r, I_m, I_{r-m} represent intensities reduced to mean solar distance. β, at head of column 9, should be $\beta_{I_{r-m}}$.

October 1936, page 349, table 2, Moose Jaw, the temperature departure "−3.2" should be blank; in same table, Medicine Hat, for temperature departure insert "+1.5".

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STRUCTURE AND MAINTENANCE OF DRY-TYPE MOISTURE DISCONTINUITIES NOT DEVELOPED BY SUBSIDENCE

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INTRODUCTION

In a previous paper (1) the author discussed in some detail the development and structure of subsidence inversions. It was pointed out that subsidence is not necessarily responsible for all inversions in which there is an abrupt fall of humidity; and that dry, warm air masses are frequently observed flowing over moister and colder currents in cases where no subsidence is indicated. For long periods of time, this warm, dry air layer can be found aloft over large sections of the country, particularly over the southern United States, and for this reason its life history presents an exceedingly important problem of synoptic meteorology. The source of this air is a controversial topic (2, 3). Indeed, the present state of the question is such that even the general classification Polar or Tropical cannot be applied with certainty; and in this report no attempt will be made to label this air mass so as to imply a certain source region or to ascribe to it any definite history. I shall be concerned merely with its existence above moister air; and for the sake of conformity with customary synoptic usage, shall refer to it as Ts air.[1]

The extremely sharp transitions in moisture observed in passing from underlying moist air masses into the *Ts* currents provide an opportunity to study several interesting questions, one of which is the thermal balance accompanying these transitions. In the case of subsidence inversions there can be little doubt that thermodynamic factors, particularly at upper levels, play the dominant role in governing the thermal conditions within the inversion layer. On the other hand, the discontinuities wherein *Ts* is the superimposed air mass seem to be governed in large part by radiative factors. This naturally implies that throughout these *Ts* currents vertical motions are comparatively small and slow acting. If this is true we may look upon the *Ts* flows as rather inert aerological entities which, because of their conditionally unstable structure, become at times catalysts in the process of rainmaking.

In this report I shall attempt to show from certain theoretical principles and observed data that there is in these discontinuities a radiative governing mechanism. The complexity of this entire problem is such that a rough approximation to a quantitative solution is as much as can be hoped for at present. It is the purpose of this paper to suggest such an approximation, or at least to suggest the more logical lines of attack, in order to obtain a solution.

[1] U. S. Weather Bureau meteorologists are now using for this air mass the designation "S", standing for superior or subsiding. At present, perhaps the most definite fact concerning this air is that it has its origin at upper levels, in contrast to other air masses which are known to have a surface source region.

STABILITY

Whatever the original cause of a humidity discontinuity, the presence or absence of condensation in the moist layer below the discontinuity will have considerable bearing on the treatment of the problem as one of radiational balance. This follows from the well-known fact that a cloud of any thickness greater than a few meters acts as a black body. The experimental investigations of the absorption spectrum of liquid water by Rubens and Ladenburg (4) form the basis for this supposition. Mal, Basu, and Desai (5) studied dry inversions on the assumption that the top of the underlying moist layer may be treated as a black body whether or not it be saturated. Their argument for this assumption is "that a haze layer is always associated with a humidity discontinuity, the maximum humidity coinciding with the top of the haze layer." Their procedure, then, treats clouds and haze layers alike with respect to radiating power. Aerological soundings in the United States show that humidity discontinuities are not always associated with pronounced haze discontinuities. Furthermore, although we have no observational data on the subject, there appears to be no sound justification for assuming that an unsaturated haze layer radiates and absorbs as a black body. The case of actual droplets of condensed water is quite different from that of a concentration of small solid haze particles, even though they be hygroscopic in nature. Though definite proof on this point is lacking, a clue is furnished by observations of inversions with and without clouds; almost invariably, those without condensation are less pronounced than those with clouds (for the same general moisture and temperature distribution). This indicates a deviation from black-body action in the moist layer underlying the inversion when clouds are absent.

Thus the quantitative treatment of dry inversions will be discussed first for an unsaturated moist base with an overlying relatively dry stratum; and later we shall deal with inversions where clouds are present.

Applicable to all cases, however, is the following consideration of the static equilibrium in a given moisture and temperature stratification: It is reasonable to suppose that the density cannot increase with height in the free air. If we assume a moisture discontinuity of the first order (mathematically abrupt) it is easy to show, as pointed out by Margules in 1906, that a temperature inversion is a static necessity, because a lapse of temperature would represent a highly unstable state which certainly could not exist aloft, for the slightest turbulence

would upset it. Let the discontinuity in moisture be at the level defined by pressure p; and let the vapor pressure in the moist air be e_1, and in the overlying dry air e_2. Let ρ_1, T_1, and R_{a1} be respectively the density, temperature, and gas constant of the air immediately below the discontinuity, and ρ_2, T_2, and R_{a2} the corresponding values in the overlying dry air. Then we have

$$\rho_1=\frac{p}{R_{a1}T_1}, \tag{1}$$

$$\rho_2=\frac{p}{R_{a2}T_2}. \tag{2}$$

For static equilibrium the following inequality must hold:

$$\rho_1>\rho_2,$$

or, from (1) and (2)

$$R_{a1}T_1<R_{a2}T_2. \tag{3}$$

The limiting case of stability is therefore

$$R_{a1}T_1=R_{a2}T_2. \tag{4}$$

But, the gas constant for damp air (R_a) is related to that for perfectly dry air (R_d) by (very nearly)

$$R_a=\frac{R_d}{\left(1-\frac{3}{8}\frac{e}{p}\right)}.$$

Substituting in (4) and rearranging, we have

$$T_2=\frac{\left(1-\frac{3e_2}{8p}\right)}{\left(1-\frac{3e_1}{8p}\right)}T_1$$

or

$$=\left(\frac{8p-3e_2}{8p-3e_1}\right)T_1$$

$$T_2=\left[1+\frac{3(e_1-e_2)}{8p-3e_1}\right]T_1. \tag{5}$$

Neglecting $3e_1$ because it is small compared to $8p$, calling $(e_1-e_2)=\Delta e$, and $T_2-T_1=\Delta T$ we have

$$\Delta T=T_2-T_1=\frac{3}{8}-\frac{\Delta e}{p}T_1. \tag{6}$$

Taking values that are frequently observed in the case of *Ts-Tg* discontinuities: $T_1=290°$A, $\Delta\, e=10$ mb, $p=800$ mb, we find that $\Delta T=1.36°$ C.

It must be remembered that in the above development we have treated the discontinuity as being mathematically abrupt. Thus the resulting ΔT will be a discontinuous change at the level of p from T_1 to T_2. Even if such a discontinuity existed in the atmosphere it would be impossible to detect with our present means of securing temperature-altitude records, for the lag of the thermometric element of the thermograph would cause a continuous rather than a discontinuous record of temperature at the level p. There would, however, be a rapid increase of temperature with elevation shown by the thermogram at this point. The fact that no such rapid increase in temperature usually occurs at the *Tg-Ts* boundary surface, but that most observed cases are isothermal layers, indicates that these transitions of moisture are not extremely abrupt. From (6) it is also clear that these so called minimal inversions are not capable of accounting for the pronounced inversions actually observed at lower temperatures and humidities. For example, let $T_1=275°$A, $e_1=6$ mb, $e_2=2$ mb, and $p=750$ mb. Then $\Delta T=0.55°$ C. With these values of T, e, and p, the observed inversions are generally of the order of 2° or 3°.

We may consider the same problem in the case of a discontinuity of second order (i. e., assuming a continuous though rapid change of vapor pressure with height). Brunt (*6*) has given such a development; for stability, Brunt finds that the following inequality must hold:

$$-\frac{\partial T}{\partial z}<0.0001+\frac{3}{8}\frac{T}{p}\frac{\partial e}{\partial z}, \tag{7}$$

where $\frac{\partial T}{\partial z}$ is the lapse rate in the transition zone; z, of course, represents elevation. (The value 0.0001 is really a close approximation to the dry adiabatic lapse rate in °C. cm).

In the limiting case, if we are to have an isothermal layer

$$\frac{\partial T}{\partial z}=0$$

which is stable, and as before, $T=290$, $p=800$, the moisture distribution is given by

$$\frac{\partial e}{\partial z}=-\frac{8\times0.0001\times800}{3\times290}=-.000735 \text{ mb/cm}=-7.35 \text{ mb/100m}$$

Now it is difficult to say what is actually the nature of the variation in vapor pressure with elevation in these discontinuities. Assuming e to be a linear function of z, which seems reasonable, and obtaining $\frac{\partial e}{\partial z}$ for some 40 *Ts-Tg* boundary layers chosen at random, the writer finds an average far less than 7.35 mb/100 m. In fact, the average of these random 40 cases was less than 2 mb/100 m, and the individual values rarely exceeded 2 mb/100 m. Computing the steepest possible lapse rate which would be stable for $\frac{\partial e}{\partial z}=2$ mb/100m we have

$$-\frac{\partial T}{\partial z}=0.0001.+\frac{3}{8}\times\frac{290}{800}(-0.0002)=0.728°\text{C./100m.}$$

From the above analysis it becomes manifest that some factor other than the maintenance of static equilibrium must be at work to produce the pronounced stability of observed moisture discontinuities. It is interesting to note that moisture discontinuities of the *Ts-Tg* type simply cannot possess very steep lapse rates—a fact which (7) clearly shows. The effect of mechanical turbulence acts in the same general direction—that is, as the lapse rate becomes steeper the upward transport of moisture increases, thereby destroying the abruptness of the humidity transition.

RADIATIVE TRANSFER ACROSS A SURFACE SEPARATING DRY AIR FROM UNDERLYING MOIST AIR

Objections to the treatment of an unsaturated moist layer as a black body have already been stated. The following development will be based on several assump-

tions which, though rough approximations, are believed to hold with sufficient accuracy to be justified.

The work of Simpson (**7**) and its extension by Brunt (**8, 9**) have opened a way to the solution of many problems of radiation which previously seemed hopelessly complex; and the success of Simpson and Brunt in applying their methods is encouraging.

From the experimental results of Hettner (**10**) on the absorption spectrum of water vapor, Simpson computed the absorption coefficients for individual wave lengths for a layer containing 0.3 mm of precipitable water per square centimeter cross section in the form of vapor. He constructed from these computations a graph showing the absorption by water vapor as a function of wave length. He then plotted on the same graph the absorption curve for carbon dioxide, reduced to the probable amount which would be present in such a layer of air. The source of his data was the experiments of Rubens and Aschkinass (**11**). From this superimposition of curves he was able to make the following generalizations:

A column of air which contains 0.3 mm of percipitable water in the form of water vapor and 0.06 gram of carbon dioxide (1) behaves like a black body for wavelengths between $5\frac{1}{2}\mu$ and 7μ and for all wave lengths greater than 14μ; (2) absorbs part, and transmits part, of the radiation it receives between 4μ and $5\frac{1}{2}\mu$, between 7μ and $8\frac{1}{2}\mu$, and between 11μ and 14μ; and (3) is completely transparent to radiation between $8\frac{1}{2}\mu$ and 11μ.

Since terrestrial radiation is all beyond 4μ, wave lengths shorter than this were not considered.

The existence of a transparent band between $8\frac{1}{2}\mu$ and 11μ, and the semitransparent bands between 4μ and $5\frac{1}{2}\mu$, between 7μ and $8\frac{1}{2}\mu$, and between 11μ and 14μ, have been found to be extremely important in the heat balance of the atmosphere as a whole.

Some objection has been raised to Simpson's application of Hettner's results on the ground that Hettner's observations were made under one pressure, and that other experimental results suggest that the absorption coefficient depends upon pressure. As far as the author knows, however, no fundamental revision of Simpson's results has yet appeared; and the success of other investigators in working with them seems to justify their use here.

Brunt (**8**) has suggested that the term "W-radiation" be used to denote that radiation composed of all the wavelengths wherein water vapor radiates and absorbs like a black body. This terminology will be used here. He has shown that the mean downward radiation R of the atmosphere on clear nights can be very well represented by a formula of the form

$$R=\sigma T^4(a+b\sqrt{e}),$$

where T is the absolute temperature and e the vapor pressure of the surface layers; σ, the Stefan-Boltzmann constant; and a and b are constants. R is composed chiefly of W-radiation, although some downward radiation comes from the semitransparent bands. An explanation of the dependence of R upon the square root of e, based upon Dennison's theory of the shape of the infrared absorption lines, has been offered by Pekeris (**12**).

The values of the constants a and b seem to differ widely for different places, and the reason for this variation probably lies chiefly in the instruments with which the observations are made. There can, however, be no doubt that the distribution of water vapor and of temperature with elevation have some effect upon a and b. Brunt's empirical formula shows that part of the downward radiation comes from some source other than water vapor. Suggestions that this source may be carbon dioxide or ozone have been made, although it has not been shown that Brunt's formula holds under low vapor pressures.

Let us now proceed to the problem of the *Ts–Tg* boundary layer. It may be stated in this way: Given a dry stratum of *Ts* air immediately overlying a moist and relatively cooler current of *Tg* air. Assuming that a radiative balance is established after a finite interval of time, what will be the general nature of this equilibrium?

The following assumptions will be made: (1) Simpson's conclusions concerning the absorption by a layer of air containing 0.3 mm of precipitable water and 0.06 gram CO_2 per square centimeter cross section are valid. (2) Brunt's formula for the downward radiation of the atmosphere holds at all levels, and the constants a and b remain the same throughout the small interval of height from the base to the top of the transition layer.

Consider, then, an abrupt transition from the *Tg* to the overlying *Ts* layer, figure 1. Divide the air above and below the discontinuity into layers each of which contains in the vertical 0.3 mm of precipitable water per square centimeter cross section in the form of water vapor; the length l of a unit column can readily be found in terms of

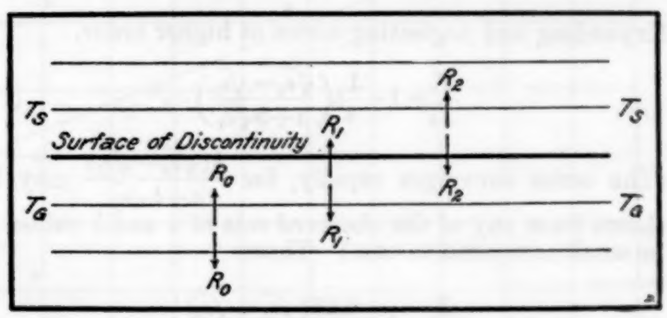

FIGURE 1.

the absolute temperature T and the vapor pressure e. If the density of the water vapor be ρ_w, its vapor pressure e, and the gas constant for water vapor R_w, then

$$e=\rho_w R_w T,$$

or

$$\rho_w=\frac{e}{R_w T}. \tag{8}$$

But $\rho_w l$ is to equal 0.3 g/cm². Thus

$$l=\frac{0.3}{\rho_w}=0.3\frac{R_w T}{e}=1.39\frac{T}{e} \text{ meters.} \tag{9}$$

The length l will in general be quite small, so that as a first approximation the temperature within one of these layers may be considered constant. For example, if $T=290$ and $e=10$ mb, l comes out about 40 meters; l will, of course, increase as T increases, and as e decreases. For radiative equilibrium in the uppermost layer of the *Tg* air, the total incoming radiation must equal the total outgoing. We need only deal with the vertical streams of radiation, assuming that the layer is of infinite horizontal extent and that other streams cancel out. The emission from this layer, then, is R_1 both upward and downward. The layer receives radiation R_2 from the overlying layer containing 0.3 mm of precipitable water vapor, and also radiation R_0 from the adjacent lower layer. For the equilibrium of this uppermost *Tg* layer, we need not be concerned with any other layers, for we are dealing

with W-radiation. Strictly, the radiation entering any layer consists not only of W-radiation but also of some semitransparent radiation, a small part of which is absorbed; it is assumed that this is negligibly small compared to the total W-radiation. Thus for equilibrium:

$$R_1+R_1=R_2+R_0. \tag{10}$$

But in the moist $T\sigma$, R_0 is practically equal to R_1, for l is small and hence the temperatures of the two uppermost $T\sigma$ layers are practically the same. Then from (10)

$$R_1=R_2; \tag{11}$$

but

$$R_1=\sigma T_1^4(a+b\sqrt{e_1}) \text{ and } R_2=\sigma T_2^4(a+b\sqrt{e_2}).$$

Substituting in (11) and rearranging,

$$\left(\frac{T_1}{T_2}\right)^4=\frac{a+b\sqrt{e_2}}{a+b\sqrt{e_1}}, \tag{12}$$

or

$$\frac{T_1}{T_2}=\left(\frac{a+b\sqrt{e_2}}{a+b\sqrt{e_1}}\right)^{\frac{1}{4}}=\left[1+\frac{b(\sqrt{e_2}-\sqrt{e_1})}{a+b\sqrt{e_1}}\right]^{\frac{1}{4}}.$$

Expanding and neglecting terms of higher order,

$$\frac{T_1}{T_2}=1+\frac{1}{4}b\left(\frac{\sqrt{e_2}-\sqrt{e_1}}{a+b\sqrt{e_1}}\right). \tag{13}$$

(The series converges rapidly, for $\frac{b(\sqrt{e_2}-\sqrt{e_1})}{a+b\sqrt{e_1}}$ may be shown from any of the observed sets of a and b values to be small compared to one.) Thus

$$\frac{T_1}{T_2}=1-\frac{0.25(\sqrt{e_1}-\sqrt{e_2})}{\left(\frac{a}{b}+\sqrt{e_1}\right)},$$

or

$$T_1=T_2-\frac{0.25(\sqrt{e_1}-\sqrt{e_2})T_2}{\left(\frac{a}{b}+\sqrt{e_1}\right)} \tag{14}$$

If we set $\beta=\frac{0.25T_2}{\frac{a}{b}+\sqrt{e_1}}$ and call $T_2-T_1=\Delta T$, (14) becomes

$$\Delta T=\beta(\sqrt{e_1}-\sqrt{e_2}), \tag{15}$$

which, then, should give the magnitude of the inversion. While T_2 and e_1 are easily obtained from upper air soundings through $T\sigma$–Ts boundaries, a and b values are not available. However, from the sets of values given by Brunt (8), a is always much larger than b; in the average of his data for six places of observation, a comes out about six times as large as b. The relatively small variations of e_1 in the denominator of the fraction representing β will, therefore, be of small consequence in the variation of β. Similarly, the percent deviation in T_2 in the numerator is quite small. It is probable then that the greatest variations in β are caused by the variation of the constants a and b. It seems safe to assume that a and b change chiefly because of the variation of the moisture and temperature distribution with elevation. If, then, we choose data from $T\sigma$–Ts discontinuities where T and e are similarly distributed, we should be able to determine the appropriate value of β.

A complication arises from the fact that abrupt discontinuities do not exist in Nature, but are transformed into transition zones through the action of turbulence. If, then, we assume that a particle in the Ts air, after having reached radiative equilibrium immediately above the discontinuity, is carried adiabatically to the top of the transition zone, we may replace ΔT in (15) by $\Delta\theta$, where $\Delta\theta$ is the difference in potential temperature between the base and top of the transition zone. Thus

$$\Delta\theta=\beta(\sqrt{e_1}-\sqrt{e_2}),$$

or

$$\beta=\frac{\Delta\theta}{\sqrt{e_1}-\sqrt{e_2}}. \tag{16}$$

In order to test the validity of the above reasoning it is necessary to have appropriate aerological soundings in which the records of temperature and particularly humidity are reasonably accurate. Ascents in relatively warm air are peculiarly well adapted for this study, for it is well known that the hair hygrograph reacts more quickly and registers more reliably under an environment of higher temperatures. The errors in the recorded humidity during aerological soundings appear to be due in large part to the lag of the hair used in the hygrograph. Spilhaus (**13**) has recently made a fundamental study of the transition rate of the human hair, suggesting methods by which the lag constants appropriate to any particular hair hygrograph may be determined. It is to be hoped that in the future these corrections will be applied. Until this procedure is adopted generally, investigators must place upon the hygrograph records an interpretation of their own. Indeed, synoptic meteorologists (**14, 1**) have been doing this very thing for some time. It is likewise necessary in the preset discussion to "interpret" the records. This does not mean that particular records were modified to fit the theory; all humidity values were used *as recorded*. It is in explaining deviations from the theory that interpretation is helpful.

If there were available perfect soundings which penetrate moisture discontinuities of the type under discussion, and if the balance suggested above were always effective, we might plot on a graph the appropriate values of $\Delta\theta$ (the difference in potential temperature through the transition zone) as ordinate and the corresponding values of $\sqrt{e_1}-\sqrt{e_2}$) as abscissa. If β were constant, we should expect in accordance with (16) to obtain a straight line passing through the origin, the slope of which would give the value of β. The writer has taken at random 41 cases of abrupt moisture discontinuities in which a dry stratum overlay a moist and potentially colder layer. For reasons given above, the selection was restricted to soundings made through relatively warm air masses. Cases in which the base of the discontinuity was below 1,000 meters were not included, because of the complexity of effects observed within the surface layers. Cases in which a cloud layer covered more than five-tenths of the sky were also eliminated, for here it seems logical to assume that a different type of equilibrium (discussed in the next section) obtains. Of the 41 cases, 13 contained clouds covering five-tenths or less of the sky; the remaining 28 cases were entirely free of clouds.

In figure 2, $\Delta\theta$ is plotted as ordinate against $(\sqrt{e_1}-\sqrt{e_2})$ for the 41 cases. The straight line, drawn from inspection,

appears to fit the observed points fairly well, corresponding to a constant slope $\beta=4$; open circles designate those points which deviate most widely from the straight line. To offer an explanation of these deviations, it is necessary to inspect the original records from which the values were obtained. The particular soundings are shown in figure 3; those in the upper half of the figure are the flights corresponding to the open circles above the line in figure 2 and those in the lower half to the open circles below the line. Numbers beside the soundings are the specific humidities at the respective levels. Arrows indicate the points chosen as the upper and lower boundaries of the transition zone. The outstanding distinction between the soundings in the upper and in the lower half of figure 3 is that the upper soundings indicate that the recorded values of specific humidity at the upper boundary of the transition zone are much too high. It is reasonable to assume that above the transition zone the variation of the moisture content with elevation is very small compared to the variation within the transition zone; this is clearly demonstrated by the older kite soundings wherein a much slower rate of ascent of the meteorograph made possible more reliable humidity measurements. Yet in the soundings referred to, the specific humidities at the first significant points above the upper arrows (the tops of the transition zones) are decidedly lower than those at the tops of the corresponding transition zones. Take, for example, the sounding at Oklahoma (OL) City on June 17, 1935. Here the humidity apparently falls from 6.6 g/kg at 2,990 m to 3.2 g/kg at 4,300 m, in spite of the adiabatic lapse rate within the intervening layer; this seems highly improbable. Again, take the case of OL on August 1, 1935. The specific humidity is recorded as falling off from 8.6 g/kg to 4.5 g/kg from 2,100 m to 3,190 m; it is much more probable that in passing through a transition zone of only 280 m, as in this case, the hygrograph did not have sufficient time to record true values. In view of the probability that e_2, the vapor pressure at the top of the transition zone, is much too large and hence that $(\sqrt{e_1}-\sqrt{e_2})$ is actually larger than recorded, it seems likely that all the crosses above the straight line in figure 2 should be displaced to the right. The ascents in the lower half of figure 3 indicate errors in the same direction, but here the probable errors are comparatively small. In fact, all these lower ascents indicate an unusual sensitivity of the hygrograph. Take for example the sounding at San Antonio (ZN) on June 17, 1935. The recorded specific humidity falls off from 13.4 g/kg to 7.3 g/kg from 1,590 m to 1,850 m. The fact that at 2,900 m the specific humidity is only 0.5 g/kg lower than it is at 1,850 m indicates that the value at 1,850 m is approximately correct. It is probable, then, that the crosses well above and those well below the line represent two extremes: the former corresponding to unusual sluggishness of the hygrograph, the latter to unusual sensitivity. The points represented as crosses would assumedly fall more nearly along a straight line if more reliable values of e_2 were available. The other points in figure 2 may thus be considered to represent cases in which the hygrograph behaved normally and similarly. It is these cases from which we must ascertain the most probable value of β. It is obvious that the true value will be somewhat below that given by the slope of the straight line in figure 2.

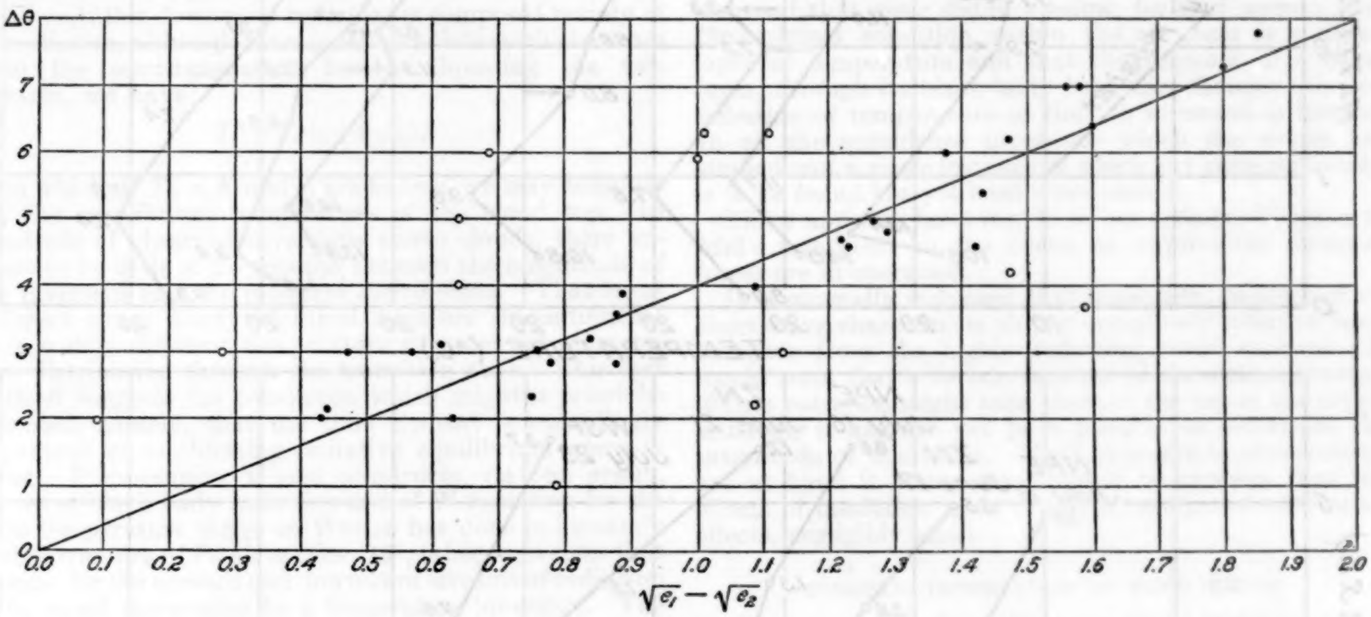

FIGURE 2.

While $\Delta\theta$ enables one to compute the difference in entropy through the transition zone, it is impossible from the above analysis to find its thickness. Clearly, this should depend upon the degree of turbulence. Qualitatively we should expect the thicker zones of transition to be formed when the overlying dry air is not much warmer than the underlying moist stratum, when the lapse rates in the air masses are steepest, and when the wind shear at the discontinuity surface is most pronounced. In the limited set of data used, some evidence of these factors appears, although it is not conclusive. This phase of the problem appears to be extremely complicated, and here no attempt to treat it will be made.

Because clouds act as black bodies, the currents of radiation emanating from their upper surfaces are appreciably greater than the W-radiation of unsaturated air with the same temperature and moisture content. In general, then, we should expect a greater loss of heat from the base of the moisture discontinuity when cloud forms are present. Therefore, $\Delta\theta$ and consequently β will be larger with clouds at the inversion base. The previous analysis obviously

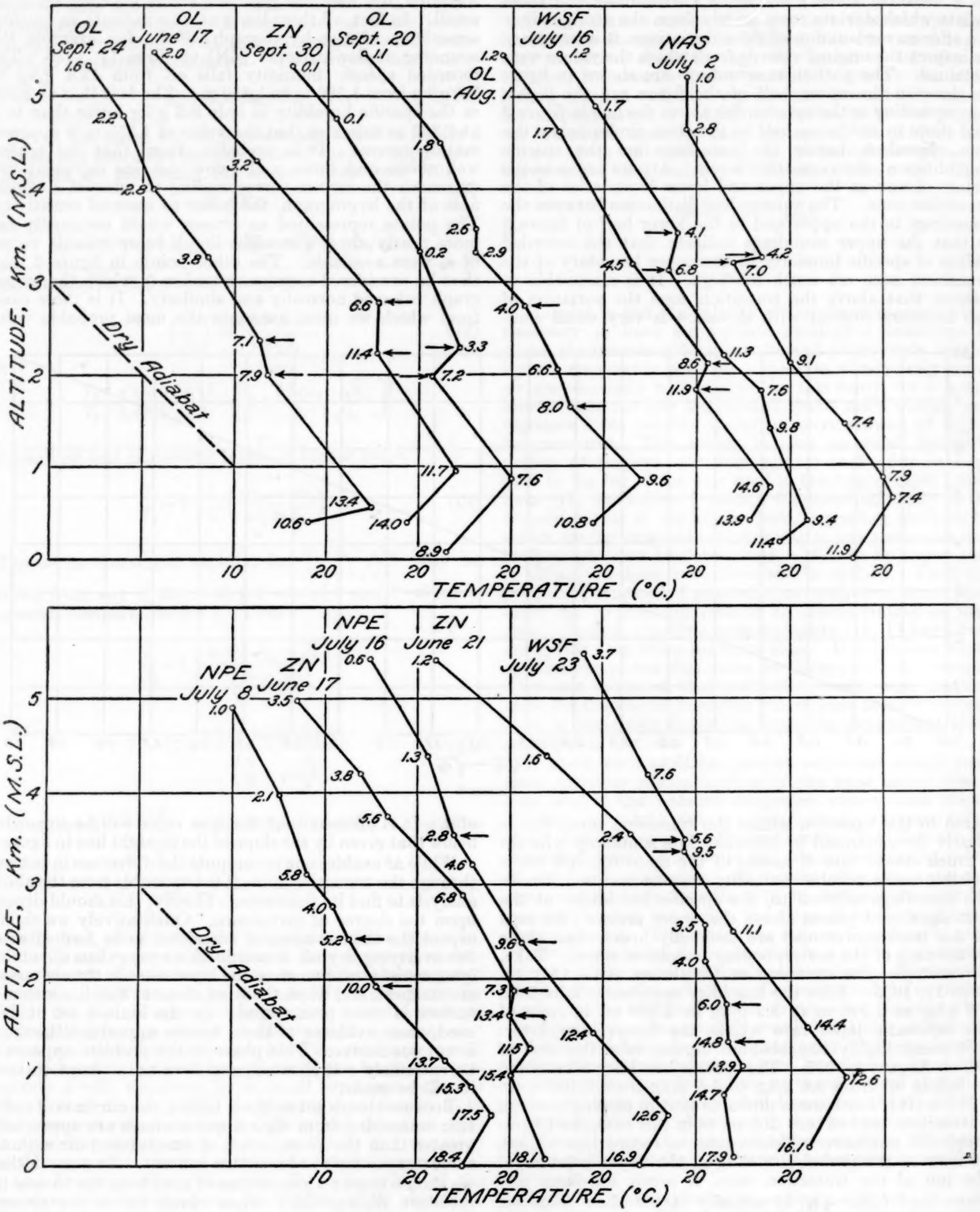
OL Sept. 24
OL June 17
ZN Sept. 30
OL Sept. 20
OL Aug. 1
WSF July 16
NAS July 2
Dry Adiabat
ALTITUDE, Km. (M.S.L.)
TEMPERATURE (°C.)
NPE July 8
ZN June 17
NPE July 16
ZN June 21
WSF July 23
Dry Adiabat
ALTITUDE, Km. (M.S.L.)
TEMPERATURE (°C.)

FIGURE 3.

does not hold when a cloud deck is present; it is interesting, however, to note the extreme divergence of β values when clouds cover more than five-tenths of the sky. A plot of $\Delta\theta$ against $\sqrt{e_1}-\sqrt{e_2}$ in 20 such cases shows no systematic arrangement of points. Furthermore, the average β for these 20 cases is 16.9, a value which is greater than any individual value of the noncloudy cases shown in figure 2. The cases in which clouds covered five-tenths or less of the sky have an average β of 6.2 compared to 4.15 for the noncloudy cases, showing the expected trend.

INFLUENCE OF CLOUDS

In the foregoing section it has been pointed out that by virtue of its black body behavior a cloud at the base of a moisture discontinuity modifies the radiative transfer. The upward current of radiation R_1 from the top of the cloud may thus be represented by $R_1=\sigma T_1^4$. The downward current R_2 which must equal this in radiative equilibrium may be expressed by Brunt's formula $R_2=\sigma T^4 (a+b\sqrt{e_2})$; this downward radiation is composed mainly of W-radiation, although there is some radiation which comes from the semitransparent bands. Equating the two streams, we have

$$T_1^4=T_2^4(a+b\sqrt{e_2}),$$

from which, if T_2, a, b, and e_2 are known, we may compute T_1, the equilibrium temperature of the cloud top. In hundreds of observed inversions above clouds, there appears to be little or no relation between the magnitude of the inversion and the moisture distribution. That is, at different times nearly identical moisture discontinuities have widely different temperature or potential temperature distribution through the transition zone. This fact in itself suggests the conclusion which might *a priori* be expected, namely, that the time element is exceedingly important in establishing radiative equilibrium above a cloud. Furthermore, if one constructs, on one graph, curves of black body radiation and of W-radiation for the same temperature range as Wexler has done in his study of the structure of *Pc* air masses (**15**), it becomes clear that in order for the upward and downward streams of radiation to be equal there must be a tremendous inversion. The excessive surface inversions found in *Pc* air source regions bear this out. Because no such inversions are ever observed in the upper atmosphere in migratory air masses, it must be concluded that conditions do not maintain their status quo sufficiently long for equilibrium to become established. Probably the chief reason for the slowness of the cooling process lies in the fact that the cooling of the cloud readily extends downward because of the necessary upward transfer of heat through convection occasioned by the steepened lapse rate. In this manner the loss of heat from the cloud is supplied by a fairly thick layer, and the cooling process goes on at a slow rate. Early morning ground inversions, on the other hand, generally exceed dry inversions in the free air because here the chief source of heat compensation is the surface of the ground, which can communicate heat to the overlying air only as fast as it is supplied by molecular conduction from the layers of earth below the surface and the warmer air above. The latter process is clearly much slower than the convective transport operative below the cloud. There are many conceivable reasons for the upset of conditions which leads to the dissipation of the cloud or perhaps to the establishment of a different moisture distribution, and here we need mention only such factors as turbulent exchange, vertical motions, and air mass modification.

Thus it is of no use to attempt to find values of a and b through observations.

An interesting theoretical treatment of this problem has been offered by Mal, Basu, and Desai (**5**), who consider the change in lapse rate with time brought about by the presence of a cloud sheet at the base of a moisture discontinuity. These investigators dealt solely with W-radiation, considering that the effect of radiation in the semitransparent bands was relatively inconsequential. Perhaps the most uncertain part of their analysis lies in the evaluation of the coefficients of radiative diffusivity and eddy conductivity. The writer has previously pointed out (**1**) that their treatment of subsidence as a possible factor in the development of dry inversions was incomplete, since they merely considered that form of subsidence brought about by the frictional outflow from the lowest layers of an anticyclone, neglecting the more important effects of horizontal divergence. Furthermore, if their analysis held, one would expect an approximate continuity in lapse rate between the air above the inversion and that some distance below, for they assume that the original condition within the air mass is a linear lapse of temperature and that the presence of a cloud layer, through its black body behavior, changes this distribution of temperature so that an inversion is formed. In all the subsidence inversions which the writer has studied, not a *single* instance in which any such continuity is to be found has yet been encountered.

There appears, however, to be no serious objection to Mal's treatment in the event no appreciable dynamic forces are in operation.

It is generally supposed that insolation, because of its short wave character, is almost completely reflected back to space from the highly reflecting cloud surfaces. It would seem that a certain amount of absorption through diffuse radiation might take place at the top of the cloud, although it has not yet been possible to determine the magnitude of this effect. Until appropriate observations are at hand it seems most logical to suppose that the effects of insolation upon clouds is, compared with other effects, negligibly small.

SYNOPTIC IMPORTANCE OF EQUILIBRIUM

If the two types of equilibrium outlined in the preceding sections actually tend to prevail at moisture discontinuities, some light is thrown upon several questions important to synoptic meteorology. It has long been observed that clouds are generally colder than the clear spaces making up the environment at the same level. This phenomenon was for a time embarassing to the proponents of the theory of penetrative convection, but now it is quite generally accepted that the cooling is due to the inertial movement of the saturated mass of air beyond its equilibrium level. It seems possible, however, that these horizontal gradients of temperature may in part be due to the difference in radiative balance discussed in the foregoing sections; this difference in balance, and evaporation as well, would naturally make the clouds colder at their tops than the surrounding dry air.

It is also conceivable that the difference of radiative effects may play a part in the development of convectional thunderstorms. Although an energy diagram based on a sounding made in the morning hours may indicate conditions favorable for the formation of thunderstorms, yet later in the day upper air indications may be unfavorable After cumulus clouds have formed, and built up to the base of the mositure discontinuity, they must affect appreciably the temperature distribution both below and

above the discontinuity, for a black body surface has been substituted for one emitting only W-radiation. Assuming that the effects of insolation are unimportant, there must therefore be a net loss of heat from the cloud top and a smaller gain of heat in the unsaturated air above the discontinuity, for much of the black body radiation of the cloud passes unabsorbed through the transparent bands of the unsaturated air. This heat is probably supplied mainly by the internal energy of the air at the cloud level. It should be noted, however, that the formation and development of the cloud is a process wherein heat is transferred through convection from the lower insolation-heated levels to the upper levels. If there is an appreciable loss of heat at the level of the cloud top, the stability of the transition zone above it must be increased. In this manner more work must be done by the rising cloud mass in order to penetrate the more stable layer and develop to thunderstorm proportions.

Surfaces of subsidence may also be modified appreciably by radiation influences. Some of these effects were mentioned in a previous paper (1). With limited data on subsidence inversions, the analysis discussed above would not be applied with reasonable success; that is, there appeared to be no general agreement in the computed values of β. In many cases it was obvious that the humidity values were at fault, for subsidence inversions appear to be restricted to the colder air masses where the hydrograph is least reliable. Aside from the errors in the measurement of humidity, it seems probable that for the most part the effect of radiation upon noncloudy subsidence inversions is small compared with thermodynamic effects. In order to obtain a value of β agreeing with the above value of 4, subsidence inversions where $\Delta\theta$ is 6° C. would have to have a moisture discontinuity wherein $\sqrt{e_1}-\sqrt{e_2}=1.5$. If e_1 is 6 mb, a not uncommon value, then e_2 would have to be 0.9 mb. A discontinuity having these values has probably never been measured in a layer of a few hundred meters thickness, and it is hard to imagine its presence in one and the same air mass. It should be pointed out, though, that β may be a function of the temperature and moisture distribution, or that Brunt's downward radiation formula may not hold at low moisture contents. The very fact that subsidence inversions show markedly varying values of $\Delta\theta$ for similar moisture discontinuities seems to indicate that thermodynamic factors are more significant in their maintenance than radiation.

It is interesting to note that some 50 subsidence inversions showed in the mean a remarkable constancy of equivalent temperature through the inversion. In fact, the *mean* equivalent temperature at the base of these inversions was 274.1° A, while that at the top of the inversion was also 274.1° A! This agreement strongly indicates the presence of a convection mechanism pictured by Rossby (16); in his treatment Rossby arrived at the final distribution of temperature and moisture in and just above a layer stirred so that convective equilibrium is reached. The relevant conclusion as stated by Rossby is: "Thus, in the case of convection with condensation the theory indicates that there must be a temperature inversion at the upper boundary of the convective layer and this inversion must have such a value that the equivalent potential temperature and therefore also the equivalent temperature remain constant." [2] It is true that condensation is not always present at the base of a subsidence inversion, but the relative humidity at this level is practically always very close to 100 percent, and it is probable that condensation sets in from time to time. The alternate appearance and disappearance of ACu clouds at subsidence inversions seems to indicate that this is true.

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[2] Strictly speaking, the constancy of equivalent potential temperature through an inversion does not imply the constancy of equivalent temperature. For conditions observed within the atmosphere, however, the variation is negligibly small.

LONG-PERIOD WEATHER CHANGES AND METHODS OF FORECASTING

By HENRY HELM CLAYTON

[Canton, Mass., July 1936]

I. BASES OF FORECASTS

Two distinct periodic changes are recognized in meteorology: One a daily, the other an annual, period. These are clearly related to the changing position of the sun. In addition to these daily and annual periods there are series of apparently irregular changes which are called the weather.

The irregular changes from day to day are found to be associated with centers of high and low pressure, and with air masses of different origins. The variations shown by weekly, monthly, or annual means are thought by some meteorologists to be the unbalanced means of daily changes and hence purely fortuitous. Others like myself believe them to be the results of large atmospheric movements of orderly procedure, and hence predictable when understood.

When the annual and daily periods are eliminated and the departures of many stations are plotted on maps over a large area, as for example the United States, it is well known that there appear distinct areas of plus and minus departures, usually with well defined centers showing maximum departures. These areas are generally several hundred miles in extent. Henryk Arctowski has proposed the names *meion* and *pleion* for them; these names are derived from the same Greek roots (viz, *meion*, less, and *pleion*, more) as the geological terms *Miocene* and *Pliocene* (variants of which are *Meiocene* and *Pleiocene*), usually pronounced "my-o-seen" and "ply-o-seen", respectively. The names are easily remembered, since *meion* signifies an area of minus departures, and *pleion* an area of plus departures. They are purely descriptive and involve no theory of their origin and hence will probably be acceptable to all parties. Whether *meiopleion* will be acceptable as a general term involving both areas is less certain.

These departures from normal may be for different intervals of time as, for example, departures of daily means from normal, departures of weekly means, monthly means, annual means, or the means of other intervals of time. Hence, to describe fully such *meions* and *pleions* a statement of the interval of time is needed so that there would occur such expressions as daily *pleions*, weekly *pleions*, monthly *pleions*, annual *pleions*, 11-year *pleions*, etc.

The departures for different elements may be designated by suffixes, as, for example, *baropleions* for pressure departures, *thermopleions* for temperatures, departures, and *ombropleions* for departures of rainfall from normal.

In describing the process of smoothing in part III, I also suggest a new term, namely, *harmons* for data smoothed by harmonic terms rather than by the ordinary numerical process.

My researches on weather changes of long period began more than 50 years ago and my present views can best be explained by the step-by-step development of my researches. In my first study I eliminated the annual period in pressure at a number of stations in the United States for the period 1874 to 1881 by taking the means of every 12 months, adding 1 month and dropping 1 month progressively. Such means have been variously called progressive means, overlapping means, moving means, running means, or chain means.

When such means for 16 widely separated stations in the United States were plotted in curves and on maps they showed several important facts:

(1) There were marked oscillations in pressure about 25 months in length, during the period covered by the observations. These oscillations were combined with a longer oscillation, which was separated from the shorter period by getting moving means of 25 months. These are shown by the graphs in figure 1. The continuous curves are the plots of the 12 monthly means and the broken curves are the means of the 25 months for four stations.

(2) The 25-month period was separated from the longer period by subtracting the 25-month moving means from the 12-month moving means. When the departures were plotted on maps they showed distinct centers of plus and minus departure separated by intervals of several hundred miles. In other words, when the pressure was above normal in one area it was below normal in some distant area. This condition is illustrated in figure 2.

(3) There was a seesaw oscillation between these areas, but in each successive return the centers of oscillation

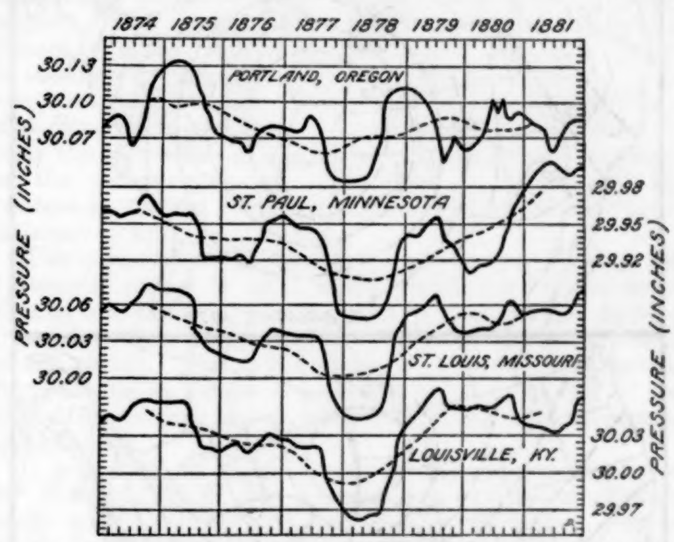

FIGURE 1.—Twelve-month means of pressure, showing oscillations of pressure of slightly over 2-year duration (see plot for St. Paul).

were displaced, showing an irregular but progressive movement. This movement is indicated by the line containing small circles in the bottom chart of figure 2. Each circle shows the progressive position of the center of maximum oscillation, whether minus or plus. The first mental picture derived from this condition was that the air over the continent grew alternately denser and rarer, such as the air might do over a vibrating metal disk; but instead of the nodes being fixed as in the case of the disk, the nodes were in movement because of irregularity in the forces causing the vibration. Later investigation showed, however, that the picture should be more like that of a disk across which waves were in progress but did not arrive at the same position after equal intervals of time because of irregularities in their velocity or direction.

When the monthly rainfalls for various sections in the interior of the United States were smoothed by 12 monthly means in the same way as the pressure, there appeared similar oscillations of about 25 months with maxima of rainfall at the time of minima of pressure.

The striking contrast between the winter temperatures during the winters when the pressure was high and those when the pressure was low is shown by the following

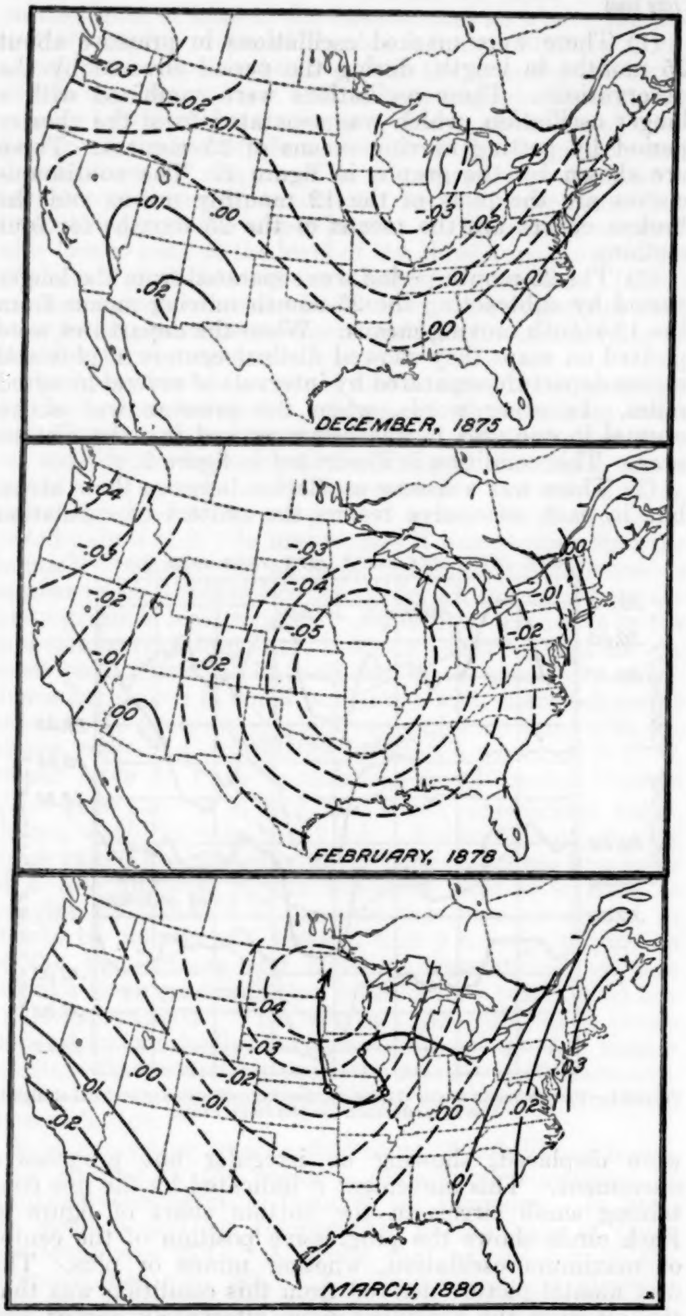

FIGURE 2.—Centers of greatest minus departure, in period of slightly over 2 years, showing movement of the center of oscillation.

departures from normal temperature taken from Dunwoody's *Signal Service Table of Rainfall and Temperature:*

	1874–75	1875–76	1876–77	1877–78	1878–79	1879–80
	°	°	°	°	°	°
Upper Lake region	−21.9	+12.4	−0.3	+32.0	−1.2	+13.9
Ohio Valley and Tennessee	−8.3	+22.1	−3.8	+17.2	−7.6	+25.1
West Gulf States	−1.3	+16.1	−7.9	+3.6	−7.0	+19.1
South Atlantic States	−0.1	+11.1	−9.0	+3.6	−4.0	+27.6

(4) Since the centers of oscillation were in movement, the phases of the oscillations were reversed in certain regions, as, for example, at stations in the eastern United States. (See fig. 2.) Hence, it would be difficult if not impossible to determine periodic changes in atmospheric conditions at any one station or group of stations in regions subject to such changes of phase.

The results of this investigation were published in the *American Meteorological Journal* for August 1884 and April 1885, volume 1, pages 130 and 528.

The next step in my investigation was to eliminate the annual and diurnal periods from observed data by getting means for many years and subtracting these mean values from the observations to obtain the irregular departures called weather. It was found that these variations under successive smoothings fell into a definite number of oscillations of longer and longer periods, from a few days to many years or even centuries. A study of these complex oscillations was given in the MONTHLY WEATHER REVIEW for April 1907 and in my book, *World Weather*, 1923, pages 111–123, 128–130, and 135–136. Examples were given of the different behavior of oscillations of different lengths and hence of the probability that they were real phenomena of our atmosphere and not merely accidental variations from mean values.

In order to illustrate these processes of smoothing in this paper the mean monthly departures from normal temperature at Chicago were successively smoothed by moving means of 5 months, 7 months, 11 months, 15 months, and 21 months, and the means placed in the middle of the interval of time covered. The results are plotted in figure 3.

It is seen that the curves are irregular; but in the smoothed values for 5 and 7 months there occur distinct maxima *a*, *b*, *c*, etc. It is evident that these are real maxima of pressure and not maxima created by the process of smoothing, because different degrees of smoothing by three, five, or seven do not change the position of the maxima. They do not disappear until the number of smoothing terms is near the length of the oscillation.

These maxima marked *a*, *b*, *c*, etc., are about 11 to 13 months apart and disappear when moving means of 11 months are obtained. In the moving means of 11 months other maxima appear which are indicated by the letters *A*, *B*, *C*, etc. These maxima are about 25 to 35 months apart and mostly disappear when moving means of 21 months are obtained. Then other maxima marked I, II, etc., appear. In other words, by means of successive smoothing, meteorological changes can be separated into a number of distinct oscillations of different lengths.

Different processes of smoothing have been studied in the development of this work and are described in part III. As a result of this study, smoothing by harmonic terms was considered the best, for the reasons set forth, and is the process of analysis now used in preparing my material for study and for forecasting. The smoothing of monthly data harmonically as now practiced by me is shown in figure 4. In examining this figure it should be noted that a 12-month oscillation is best brought out arithmetically by moving means of 6 months, but in harmonic smoothing a 12-month oscillation is best shown by smoothing with 12 terms.

When data for a network of stations are worked up in the manner shown in figure 4 and plotted on maps such as are illustrated in figure 2, the areas of *minus* and *plus* departures which we will call *meions* and *pleions* move with different velocities corresponding more or less inversely with the length of the period of oscillation. In other words, the *meions* and *pleions* of longer periods move more slowly, and frequently in different directions from those of shorter period prevailing at the same time. The shorter *meiopleions* usually move from west to east in the United

States, and only occasionally from other directions; while those of longer periods may move from any direction, sometimes from west to east or from north to south and sometimes in the opposite direction.

By following the movements of these *meions* and *pleions* their position can be estimated, and forecasts based on them, for a limited time in advance. In order to extend these forecasts for a considerable interval in advance, it is necessary to assume some sort of rhythm or regularity of occurrence in succeeding pulsations. This assumption frequently leads to disappointment, owing to changes in direction and velocity of the *meiopleions*. In order to get at the law of these changes it was necessary to ascertain their causes.

Among many efforts in this direction, a comparison was made of the pulsations of pressure and of temperature with pulsations in the values of solar radiation as measured by the Astrophysical Observatory of the Smithsonian Institution. This comparison showed many facts which indicate a close relation between the solar changes and terrestrial weather. These studies were published in the *Smithsonian Miscellaneous Collections*, between the years 1917 and 1934.

One of the early comparisons made in 1916 was that of 10-day moving means of solar radiation with 10-day moving means of temperature at stations in Argentina where I was forecast official of the Argentine Weather Service. A plot of these moving means is reproduced in figure 5. The comparison of these moving means with those of solar radiation 2 days later showed a correlation of −0.82 at Sarmiento, in southern Argentina, from which region the *meions* and *pleions* moved northeastward and took about 8 days to reach southern Brazil. Had the position of origin of the *meiopleions* remained permanent, it would have been easy to anticipate changes of temperature in South America from changes in solar radiation. Unfortunately, however, further comparisons showed that the places of origin of the *meions* and *pleions* were not constant, so that meteorological changes in any given region might be for a while positively correlated with solar changes and a little later negatively correlated with solar changes.

This fact is set forth clearly in a study presented to the American Geophysical Union in 1935. (*Trans. of the Amer. Geoph. Union*, 16th annual meeting, 1935, p. 158.) In this paper a comparison was made between an 11-month period which has been discovered in solar radiation and changes in air pressure at widely separated stations in North America. The comparison was made by means of values of solar radiation and pressure smoothed harmonically with 12 terms (see part III) and further smoothed by taking overlapping means of three periods. The results are shown by plots in figure 6. It is seen from these plots that complete reversal of the pressure oscillations as compared with solar radiation are of frequent occurrence. Moreover the inversions do not occur simultaneously at the different stations. Studies of this effect have led me to believe that it results from changes in the places of origin of the *meions* and *pleions* with changes in the intensity of solar radiation. This shifting greatly complicates the problem. The fact stands out clearly, however, that the pulsations in meteorological conditions are closely related to pulsations in solar radiation, and any periodicity which may be found in solar radiation will be reflected in terrestrial conditions.

In order to ascertain whether there were certain normal positions around which the *meions* and *pleions* oscillated, 12-month *harmons* of pressure (see part III) were computed for a network of stations over the Northern Hemisphere and at scattered stations in the Southern Hemisphere for the 10 years 1921 to 1930. The data were taken from *World Weather Records*, 1921–30; *Smithsonian Miscellanious Collections*, volume 90, 1934. During this period there were 10 distinct pulsations of solar radiation at fairly regular intervals of about 11 months. The meteorological pulsations were much less regular, but were averaged for the 10 periods at the various stations, with the hope of thereby obtaining an approximation to normal. These means were plotted on maps for each month of the period. Two of these maps are reproduced, figure 7 showing the mean position of the *meions* and *pleions* at the time of maximum solar radiation in the 11-month period, and figure 8 showing the mean position at the time of minimum solar radiation. These figures show very clearly the influence of oceans and continents. In general, with a maximum of solar radiation, diminished pressures are found over the warm waters of the tropics and over the northern continental masses; while with a minimum of solar radiation, the reverse is found.

When maps similar to figures 7 and 8 are examined for each month of the period it is found that the *meions* and *pleions* are slowly displaced and the centers of greatest departures progress along definite tracks until they disappear. The centers in the Pacific marked + and − in figures 7 and 8 moved southeastward and after about 5 months disappeared near the American coast. The centers in the western United States moved northward and disppeared in Alaska. The centers over the Atlantic near the east coast of the United States moved eastward to the waters near the north coast of Africa and the centers in central Siberia moved westward to the North Atlantic Ocean.

The progress of these *meions* and *pleions* during the 11-month period is most easily shown by curves as in figures 9 and 10. The top curve in each case is derived from the mean values of solar radiation for each month of the period. The lower curves in each case are derived from the mean values of pressure for each month of the period at stations along the tracks of the moving *meions* and *pleions*.

It is seen from figure 9 that in the central Pacific at 50° N. and 170° W. the pressure rose and fell simultaneously with the rise and fall of solar radiation, but at places further east the maxima and minima were successively delayed until the coast of California is reached. On the other hand, over the subtropical arid lands of northern Mexico and the southern United States the pressure fell and rose in opposition to the rise and fall of solar radiation; that is, the pressure fell over these regions as the sun became hotter. The maxima and minima of pressure were delayed at stations further north and did not reach Alaska until 4 or 5 months later. Over the Atlantic Ocean and Asia a similar series of events occurred (fig. 10). Over the western Atlantic the pressure rose and fell in unison with the solar radiation, and the maxima and minima of pressure occurred successively later at points further east until near the north coast of Africa there was a delay of about 5 months. Over the subtropical arid regions of northern Africa and over subtropical Asia the pressure changed oppositely to the solar change, as it did over the subtropical lands of America, and the times of maxima and minima were delayed until they reached the coast of Norway 5 months later.

There is, however, a terrestrial influence on these changes—the pressure oscillations increase in intensity as they move northward, and diminish as they move southward. The explanation of this condition is that the

wind velocities in general increase as one approaches the axis of the earth's rotation at the poles. The increased movement of the wind increases the speed and intensity of the pressure and temperature changes. This result has been explained by Ferrel and others. The changes of intensity are roughly inversely proportional to the cosine of the latitude, and can be computed with sufficient accuracy for practical purposes on that basis.

The results shown in figures 7 and 8 are all consistent with one another. They indicate that with increased solar radiation the areas of high pressure normally over

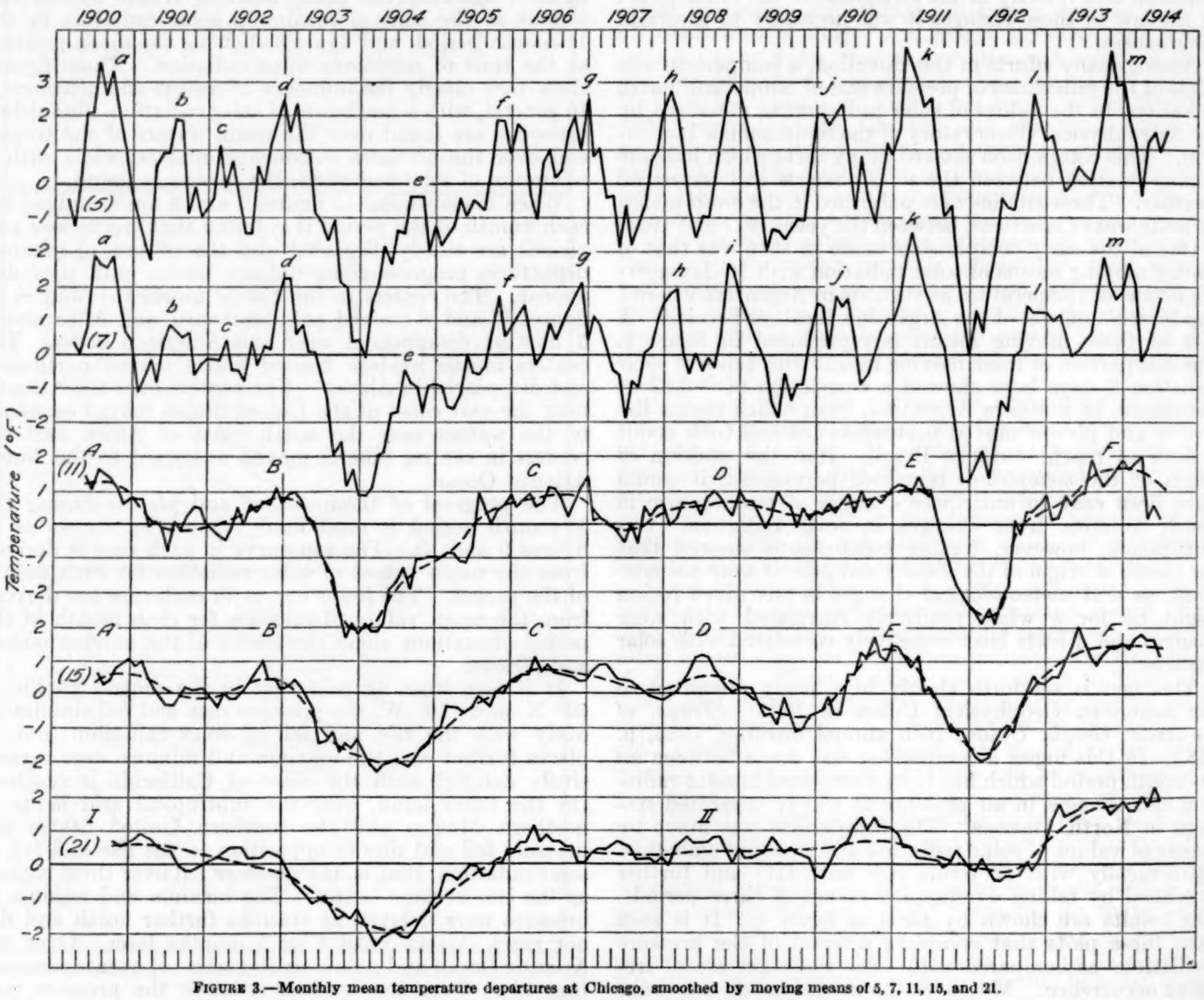

FIGURE 3.—Monthly mean temperature departures at Chicago, smoothed by moving means of 5, 7, 11, 15, and 21.

the oceans in middle latitudes are displaced northward and eastward of their normal positions, and return gradually to their normal positions with decreased solar radiation. Over the subtropical land surfaces the increased heat emitted by the sun causes a fall of pressure and this fall is propagated northward from Helwan to Bodo as shown in figure 10.

When one examines the individual periods, however, he finds that some of them vary materially from the mean; and in order to ascertain the cause of this difference I selected the 3 periods which showed the largest departures from the mean of the 10 periods averaged. The solar radiation and the pressure for these three periods were then averaged separately. Some of the curves derived from these averages are plotted in figures 11 and 12. They show that the range from maximum to minimum of solar radiation increased from 0.0060 calory to 0.0082 calory, or about 35 percent.

In the Pacific where the pressure rises and falls in unison with the solar radiation the *pleion* is displaced 20° of longitude toward the west with increased solar radiation, that is to 170° east longitude, and also some 10° of latitude toward the north. The result is that the *pleions* are some 3 to 4 months later in reaching given longitudes farther east. In the mean of all the periods (fig. 9) the maximum of pressure reached the Pacific Coast of the United States in the seventh month of the period. In the mean of three periods with higher solar radiation (fig. 11) the maximum reached the Pacific Coast in the tenth month of the period; that is, 3 months later. In the mean of three periods a *baromeion* formed in northern Mexico and Texas, as shown by the right-hand curves of figure 11, and reached Edmonton in the same months as did the mean of all 10 periods, figure 9. However, in the mean of three periods the *meion* proceeded northward toward the Arctic Ocean instead of northwestward toward Alaska.

Figure 12 shows that over the Atlantic Ocean the *baropleion* in the mean of three periods formed north of the position indicated for the mean of all in figure 9 and moved eastward to Norway. A *baromeion* formed over northern Africa as before and moved northward to Dickson in the Arctic Basin. In other words, the *pleions* over the oceans formed further north and west with increased intensity of solar radiation and were several months later in reaching middle latitudes. The *meions* also followed courses to the eastward of those followed by

took place between Bodo, Norway, and Madeira, as shown by the curves on the right-hand side of figure 13.

In the case of the sunspot period, there is found a similar set of relations with changes in the intensity of solar activity, as is shown by figure 14 taken from my paper on *World Weather and Solar Activity* (*Smith. Misc. Coll.*, vol. 89, no. 15, p. 10, May 1931).

The plots in figure 14 show that there was a seesaw oscillation in the relation of the pressure to sunspots between New York and Upernivik, and evident displace

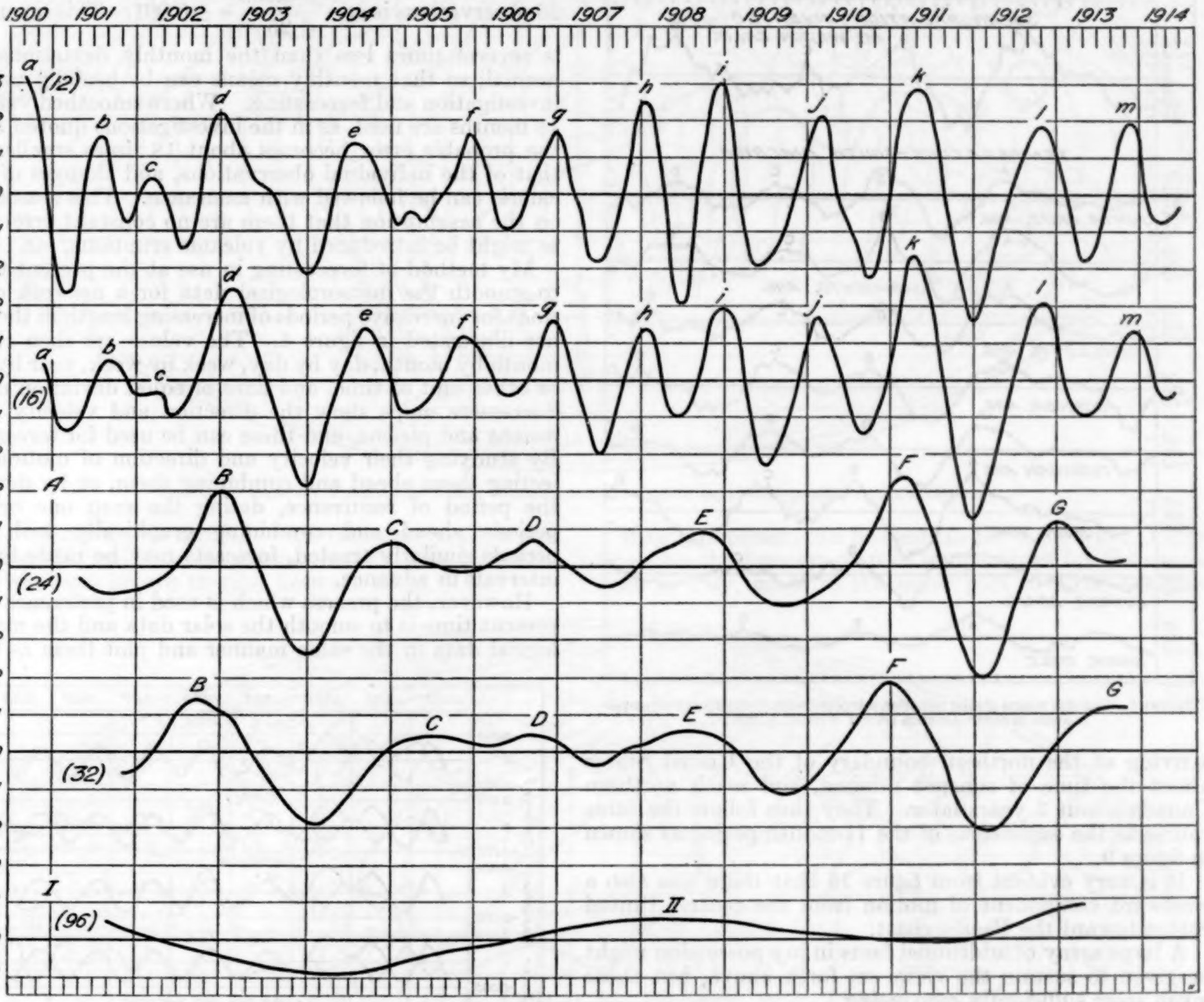

FIGURE 4.—Monthly mean temperature departures at Chicago, smoothed harmonically with 12, 16, 24, 32, and 96 terms.

the *meions* derived from mean values of all the periods and moved more nearly northward.

Another effect of the westward and northward displacement of the *pleions* over the oceans was the inversion of the pressure changes at certain places in high and low latitudes. This fact is made evident by the curves in figure 13. In the means of seven periods of lesser solar radiation shown by the curves marked *a*, the pressure followed the same course as the solar radiation at Kodiak, Alaska, and was inverted at Honolulu, Hawaii. In the mean of three periods with increased range in solar radiation the *pleion* was displaced toward the west and the pressure was inverted to solar radiation at Kodiak and was direct at Honolulu. Inversions of the same kind

ment of the *pleions* northward with increased solar activity. Also, the ranges were greatest in 1917 when the sunspots showed the greatest activity and the solar radiation averaged higher than at any time since the beginning of observations.

In general the temperature averages relatively high at sunspot maximum over the subtropical land surfaces of northern Africa, southwestern United States, and central Australia, as is shown in my book *World Weather*, 1923, page 315.

In order to study further the relation between sunspots and weather, the annual means of sunspots since 1880 were smoothed harmonically with 12 terms, and the annual means of temperature for the same period at numerous

stations in the Northern Hemisphere were smoothed in the same manner.

Plots for a series of stations running from Mexico northward are shown in figure 15, and plots for a series of stations running from Chicago westward to the Pacific Coast are shown in figure 16. It is evident from figure 15 that the *thermopleions* appear in northern Mexico soon after the sunspot maximum and progress northward,

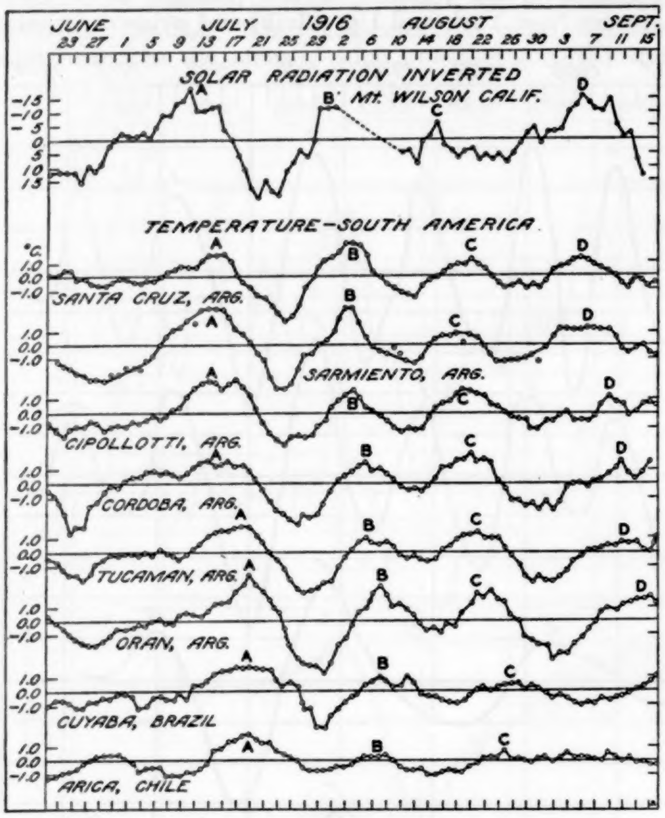

FIGURE 5.—Ten-day means of solar radiation compared with 10-day means of temperature in South America (*World Weather*, p. 223).

arriving at the northern boundary of the United States about the time of sunspot minima, and reach northern Canada about 3 years later. They thus follow the same course as the *baromeions* of the 11-month period as shown in figure 9.

It is very evident from figure 16 that there was also a westward component of motion from the central United States toward the Pacific coast.

A large array of additional facts in my possession might be given to sustain the views set forth above, but those given seem sufficiently convincing.

It seems clearly evident that there is a close relation of atmospheric changes to periodic changes in solar radiation and also to the sunspot period of about 11 years. The relation, however, is a very complex one owing largely to the change in place of origin of *meions* and *pleions* in the atmosphere with changes in the intensity of solar radiation; but my experience convinces me that we have now sufficiently unraveled the manner in which these changes occur to make useful long-range forecasts.

II—METHODS OF FORECASTING

The changes in solar intensity might be followed directly from observed values of solar radiation were the observations sufficiently accurate. This, however, is not the case. Owing to the very great difficulty in freeing the observations of solar radiation from atmospheric interference, the probable errors of these observations at present are nearly as large as the departures from the normal which are being measured. For this reason we cannot well use the day-to-day observations of solar radiation for forecasting weather.

Assuming, however, that the probable error of an individual observation is $\epsilon = \pm 0.005$ cal. (Abbot now estimates it as somewhat less), the probable error of a month with 25 observations is $\epsilon_m = \dfrac{\pm 0.005}{\sqrt{25}} = \pm 0.001$. This mean error is several times less than the monthly deviations from normal, so that monthly means can be usefully used for investigation and forecasting. Where smoothed values of 11 months are used, as in the investigations quoted above, the probable error becomes about 18 times smaller than that of the individual observations, and changes of 0.002 calorie can be followed with assurance. This reasoning is on the assumption that there are no constant errors such as might be introduced by volcanic eruptions, etc.

My method of forecasting in use at the present time is to smooth the meteorological data for a network of stations for successive periods of increasing length in the manner illustrated in figure 4. The values are then charted month by month, day by day, week by week, year by year, or other unit of time, and lines of equal deviation drawn. Successive maps show the direction and velocity of the *meions* and *pleions*, and these can be used for forecasting. By studying their velocity and direction of motion, projecting them ahead and combining them, or by detecting the period of recurrence, dating the map one or more periods ahead and combining graphically with other periods similarly treated, forecasts may be made for long intervals in advance.

However, the process which is used in preference at the present time is to smooth the solar data and the meteorological data in the same manner and plot them as curves

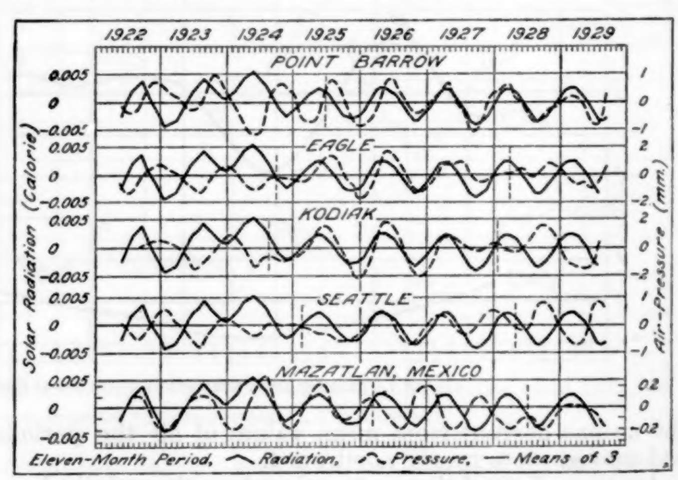

FIGURE 6.—Eleven-month period in solar radiation and in pressure.

over each other in the manner shown in figure 6. Then the relation to the solar period can easily be seen, so that the meteorological data can be extrapolated one or two periods in advance, with only occasional failures on account of changes of phase. In each case the length of a known solar period is used for the extrapolation. This is done for a succession of periods of different lengths, and the forecasted values added together to obtain the expected value at that station. This process is followed for a num-

ber of stations and the results plotted on maps. Lines of equal value are then drawn and the result is a map of expected occurrence, or a forecast, whether it be for pressure, temperature, or rainfall. All three are used, whenever possible, and checked against one another by means of the relations known to exist between them.

FIGURE 7.—Departure of pressure at time of maximum of solar radiation in 11-month period (in units of 0.01 mm).

A map of temperature departures for May 1936, made in this way during the latter part of April and actually used in forecasting the temperature of May for different sections of the United States, is shown in figure 17, while figure 18 shows the actual departures of temperature as published in the *Weekly Weather and Crop Bulletin* of the United States Weather Bureau, June 2, 1936.

Weekly forecasts can be made in the same way. Figure 19 shows the forecast map of temperature for the second week in July, made in the latter part of June, outlining the heat wave which occurred east of the Rocky Mountains during that week as shown by the data in the *Weekly Weather and Crop Bulletin* of July 16, 1936, reproduced in figure 20. The intensity of the departures was

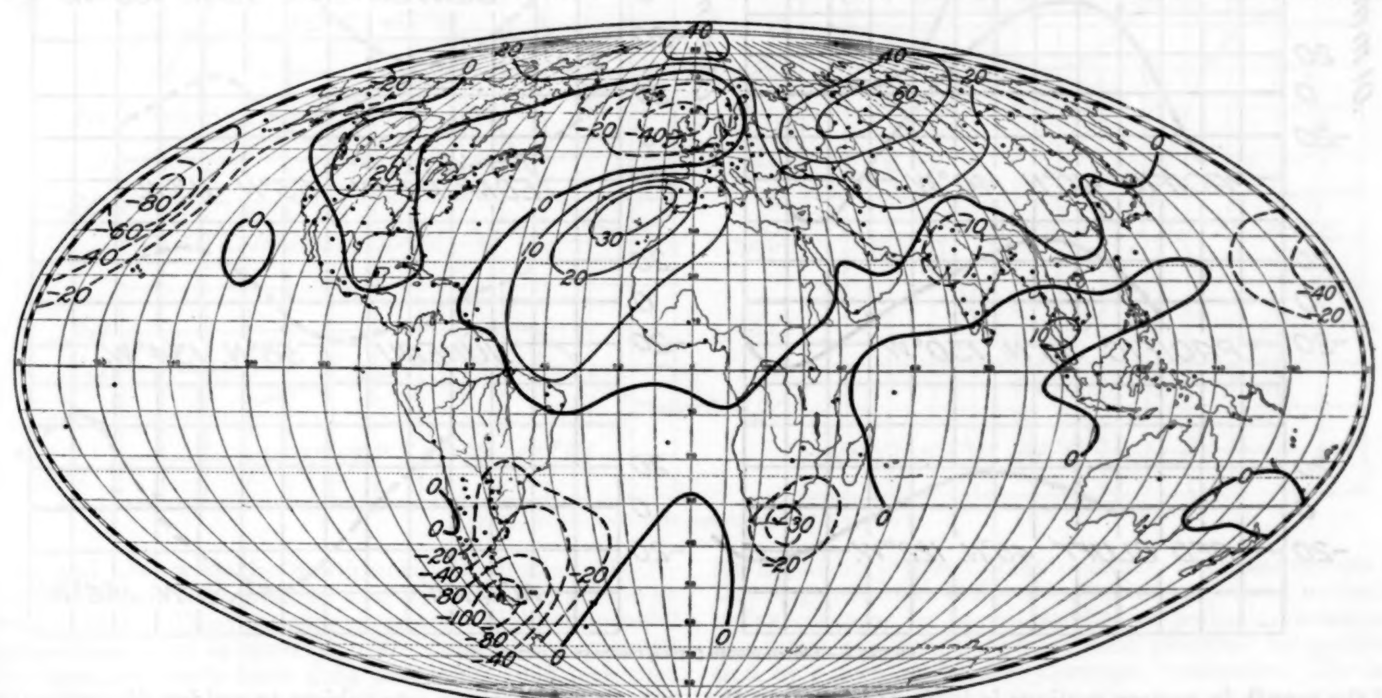

FIGURE 8.—Departure of pressure at time of minimum of solar radiation in 11-month period (in units of 0.01 mm).

not as great in the forecast map as in the observed map, but areas of excess and defect were fully 80 percent correct. Forecasts based on this map were published in my bulletins, as follows: "July promises to average warm in the eastern half of the United States and cool on the Pacific coast and Rocky Mountains. The warmest part

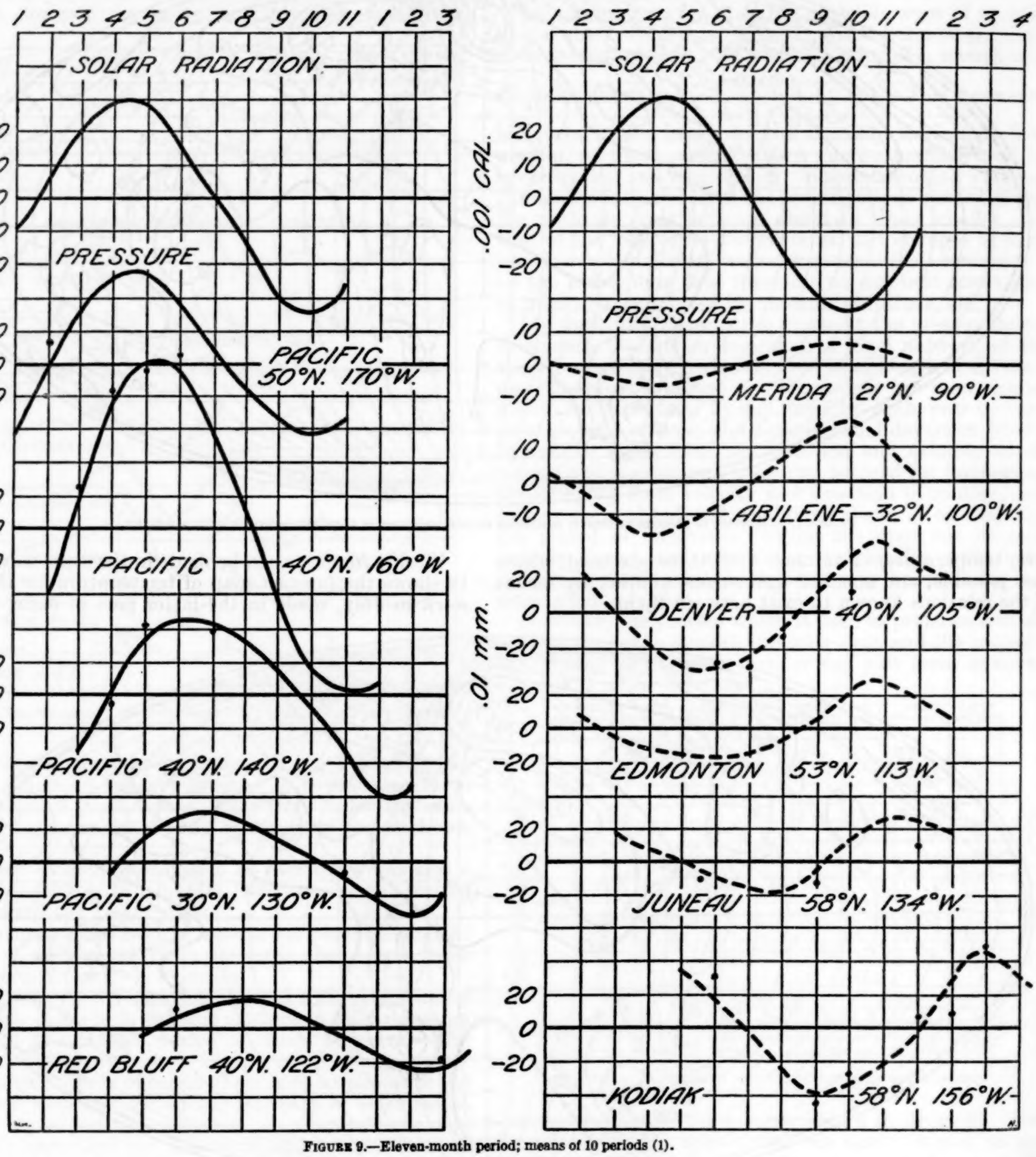

FIGURE 9.—Eleven-month period; means of 10 periods (1).

of the month in eastern sections is indicated between the 1st and 21st." It seems clear from the foregoing that practical long-range forecasts are now being made which compare favorably in accuracy with the day-to-day forecasts of the various weather bureaus of the world. Such forecasts will increase in accuracy as we come to know more exactly the lengths of the solar periods and can predict their changes in amplitude.

My early investigations of short meteorological periods led me to the belief that these periods were nearly always subdivisions of longer periods (*Science* (N. S.), vol. 7, p. 243, 1898). My first suggestion of their connection with solar periods was in connection with a period of about 7 days which I found to be nearly one-fourth of a solar rotation, but which was subject to sudden discontinuities (*Amer. Jour. of Science*, New Haven, vol. 2, p. 7, 1898). For longer weather periods, I tried subdivisions of the sunspot period and its multiples (*Nature*, vol. 51, p. 436, 1895).

Later investigations led me to try the double sunspot period of 22.5 years as the fundamental period of solar and weather changes (*Smithsonian Misc. Coll.*, vol. 82,

no. 7, p. 37). This period and its subdivisions ½, ⅓, ¼, ⅙, ⅛, etc., gave me better results than the single sunspot period. I worked out these periods in meteorological changes and made forecasts based on them. In order to eliminate the annual period I took the same month for each successive year and made forecasts for the months separately. One made for June temperatures at New Haven 4 years in advance was sent out to clients in May 1932 and filed with the Smithsonian Institution, the receipt of which was noted in a letter from Dr. Abbot on June 2, 1932. This forecast proved to be highly successful and is reproduced in figure 21. The dotted line represents the forecasts made from data preceding 1925, the part after 1931 being projected entirely into the future; the full line connects the observed departures from normal temperature.

Abbot was led by his investigations to conclude that the double sunspot period was more nearly 23 years in length (*Smith. Misc. Coll.* vol. 94, no. 10, 1935), and that the shorter periods of solar radiation were subdivisions of this length. He made forecasts of solar radiation based on this supposition, which he finds were approximately verified. He also made forecasts of meteorological changes based on the same periods (*Report on the Astrophysical Observatory*, 1935, Smithsonian Institution, Washington, D. C.).

A. E. Douglass has also been actively at work on this question of periodicity in solar and meteorological changes, having at his disposal many centuries of measurements of tree rings which he believes sufficiently represent meteorological changes to permit studies of periodic variations. His latest researches are now being prepared for publication as a memoir by the Carnegie Institution. He has shown exceptional ingenuity in this research, but my own investigations lead me to conclude that it is very difficult to determine periods of any kind accurately from meteorological data owing to frequent changes in phase and intensity of the periods. Such determinations necessarily have a large probable error.

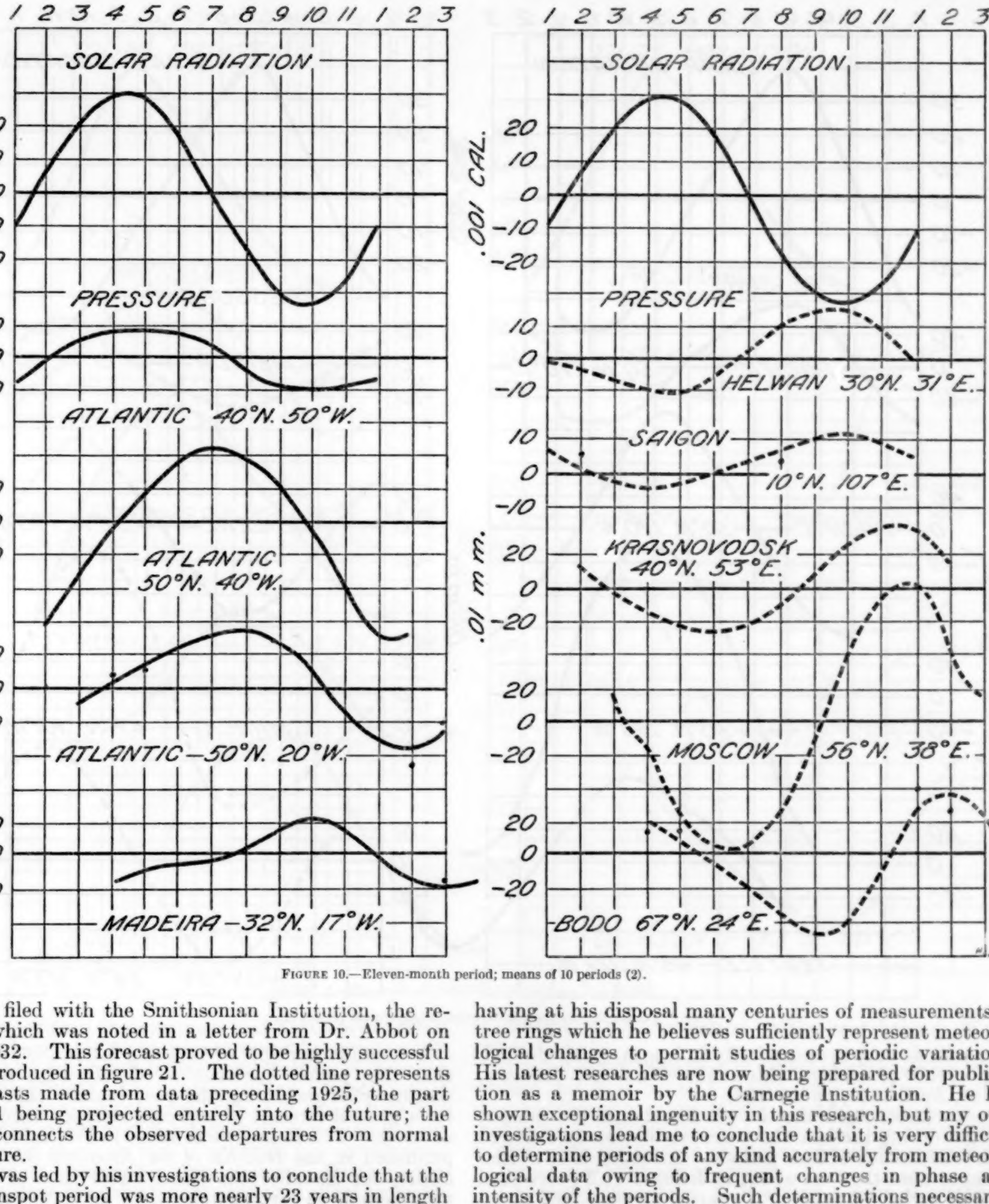

FIGURE 10.—Eleven-month period; means of 10 periods (2).

Dinsmore Alter has also studied these changes; but his use of the Schuster periodogram has not been very fruitful in results, because this periodogram assumes a constancy of phase and amplitude in the periods investigated, which apparently does not exist in solar and meteorological periods.

H. W. Clough has also investigated these relations from data covering many certuries, and has concluded that solar periods vary systematically in length, going through long cycles of change (MONTHLY WEATHER REVIEW, vol. 61, April 1933, pp. 99–108).

In my latest researches I have found that the sunspot changes during the last 150 years can be closely followed by a combination of four periods. Arranged in the order of importance they are about as follows: 11.2 years (and the half period 5.6 years), 8.4 years, 9.96 years, and about 90 years.

I find that most of the solar radiation periods so far determined are fractions of the 11.2-year or the 8.4-year periods. The 25-month period which I pointed out in the pressure some 50 years ago is one-fourth of the 8.4-year period; and the 11-month period discussed in this paper is one-twelfth of the 11.2-year sunspot period. The sunspot period varies in amplitude during the 90-year period, being greatest near the maximum of the period.

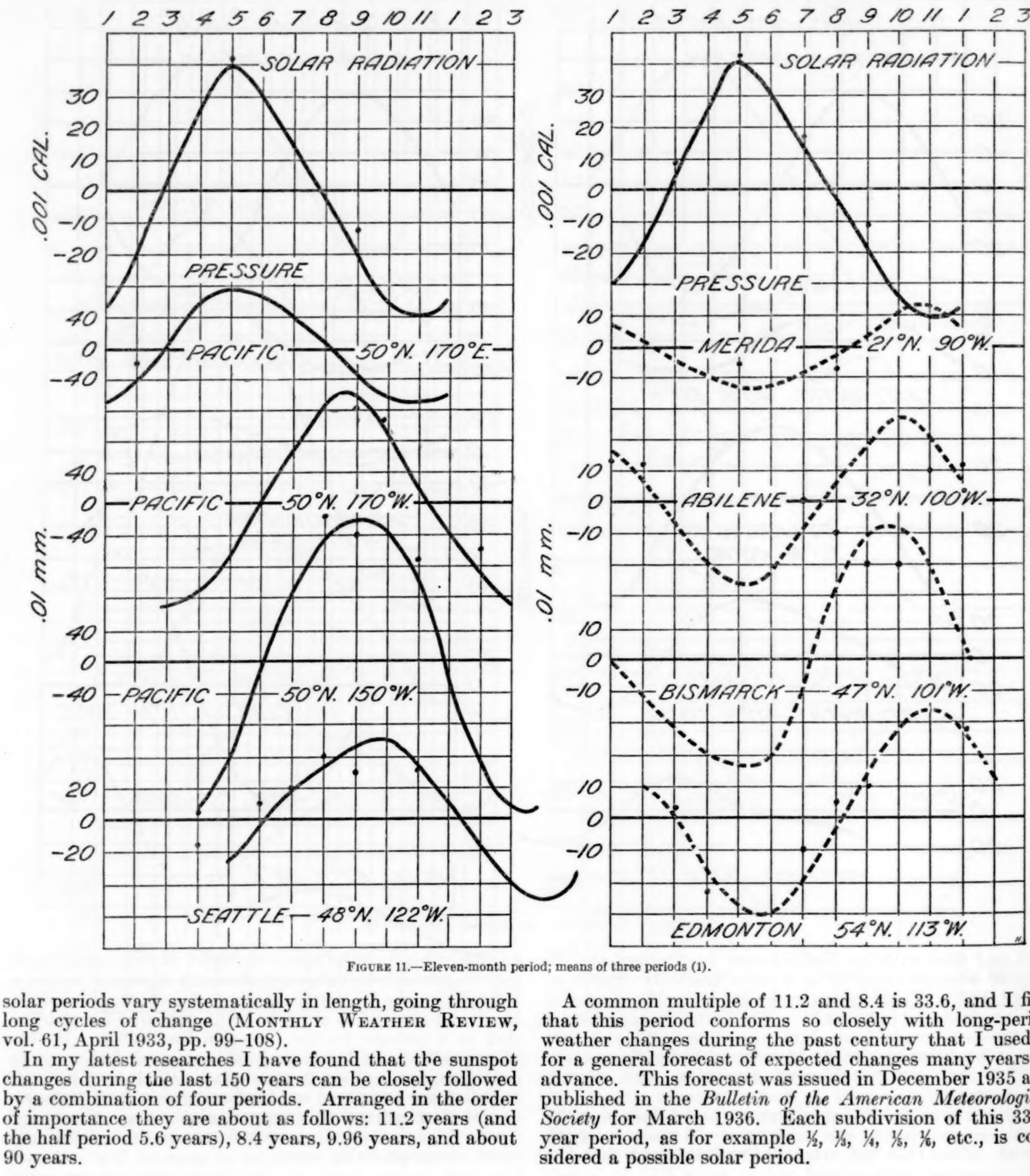

FIGURE 11.—Eleven-month period; means of three periods (1).

A common multiple of 11.2 and 8.4 is 33.6, and I find that this period conforms so closely with long-period weather changes during the past century that I used it for a general forecast of expected changes many years in advance. This forecast was issued in December 1935 and published in the *Bulletin of the American Meteorological Society* for March 1936. Each subdivision of this 33.6-year period, as for example ½, ⅓, ¼, ⅕, ⅙, etc., is considered a possible solar period.

The double period of sunspots appears also to be a solar period; and no doubt there are longer periods, such as those advocated by A. E. Douglass, Ellsworth Huntington, H. W. Clough, D. Alter, H. P. Gillette, and others in the United States, and by E. Brückner, C. E. P. Brooks, D. Brunt, H. Memery, and others in Europe.

Forecasting variations in amplitude in the solar periods is not yet attained, but it may be that they will be found to be cyclical in occurrence and hence predictable. Abbot has been able to anticipate monthly variations in solar radiation fairly well by assuming periods of constant phase and amplitude. I have also made such forecasts that show a correlation with observed values of nearly 0.60, but it seems evident that the solar periods do vary in amplitude and perhaps in phase, so that in accurate forecasting some allowance must be made for these changes. Further work needs to be done in evaluating the seasonal effect on meteorological changes, and the influence of ocean water.

C. J. Bollinger, of the University of Oklahoma, and A. Jatho and W. Hoxmark, of Buenos Aires, are now at work on such problems. L. Weickman and his pupils, and Bauer, are at work on allied problems in Germany. Julio Bustos Narvarrete is studying the problem in Chile, and Inigo Jones in Australia; also A. N. Wallis in South Africa. G. C. Simpson, Director of the British Meteorological Office has made a profound study of the influence of changes in solar radiation on the heat balance of the atmosphere.

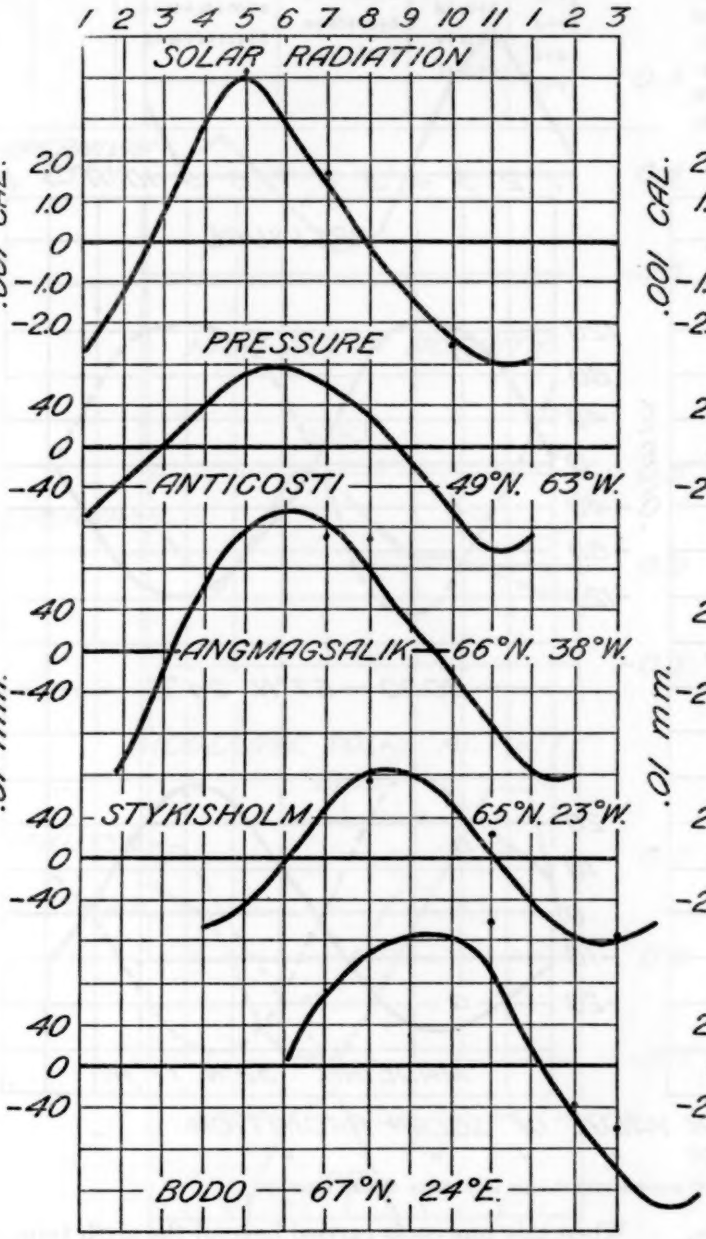

FIGURE 12.—Eleven-month period; means of three periods (2).

More accurate measures of solar radiation are urgently needed, for it is evident that a change of only a few thousandths of a calory exerts a marked change on our atmosphere. Abbot should be given all the aid possible in this work, and other physicists should be encouraged to devise new methods of attack.

The world owes John A. Roebling a debt of gratitude for the support he has rendered these researches.

III.—SMOOTHING PROCESSES [1]

When one wishes to smooth data of any kind the usual process is to give each value the same weight and get numerical means. Thus if there are a succession of values, a, b, c, d, e, f, etc., and it is desired to smooth them slightly, it is usual to get means of $a+b+c$, then means of $b+c+d$, etc. This is equivalent to multiplying each of the values by one, and dividing by the sums of the weights $1+1+1$. Where more smoothing is desired, the sums of 5 terms are used $a+b+c+d+e$, then $b+c+d+e+f$, etc., divided in each case by 5. For further smoothing the sums of 9 terms, 11 terms, or any other number may be used. This process has been given many names, as smoothing by *progressive* means, *overlapping* means, *moving* means, *running* means, *chain* means, etc. By this process of smoothing, the amplitudes of the oscillations are diminished and the maxima and minima frequently displaced from their true position.

An improvement in the process of smoothing is obtained by giving additional weight to the values near the center of the time interval; thus, in the case of three values the central value is given double weight and the formula becomes $a+2b+c$ divided by 4, the 4 being the sum of the weights. Or in the case of five values the formula becomes $a+4b+6c+4d+e$ divided by 16. This process of smoothing is best done by getting successive sums of two as illustrated in the following table:

Observation values	First sum	Second sum	Third sum	Fourth sum	Fifth sum	Etc.
a						
	$a+b$					
b		$a+2b+c$				
	$b+c$		$a+3b+3c+d$			
c		$b+2c+d$		$a+4b+6c+4d+e$		
	$c+d$		$b+3c+3d+e$			
d		$c+2d+e$		$b+4c+6d+4e+f$		
	$d+e$		$c+3d+3e+f$			
e		$d+2e+f$				
	$e+f$					
f						

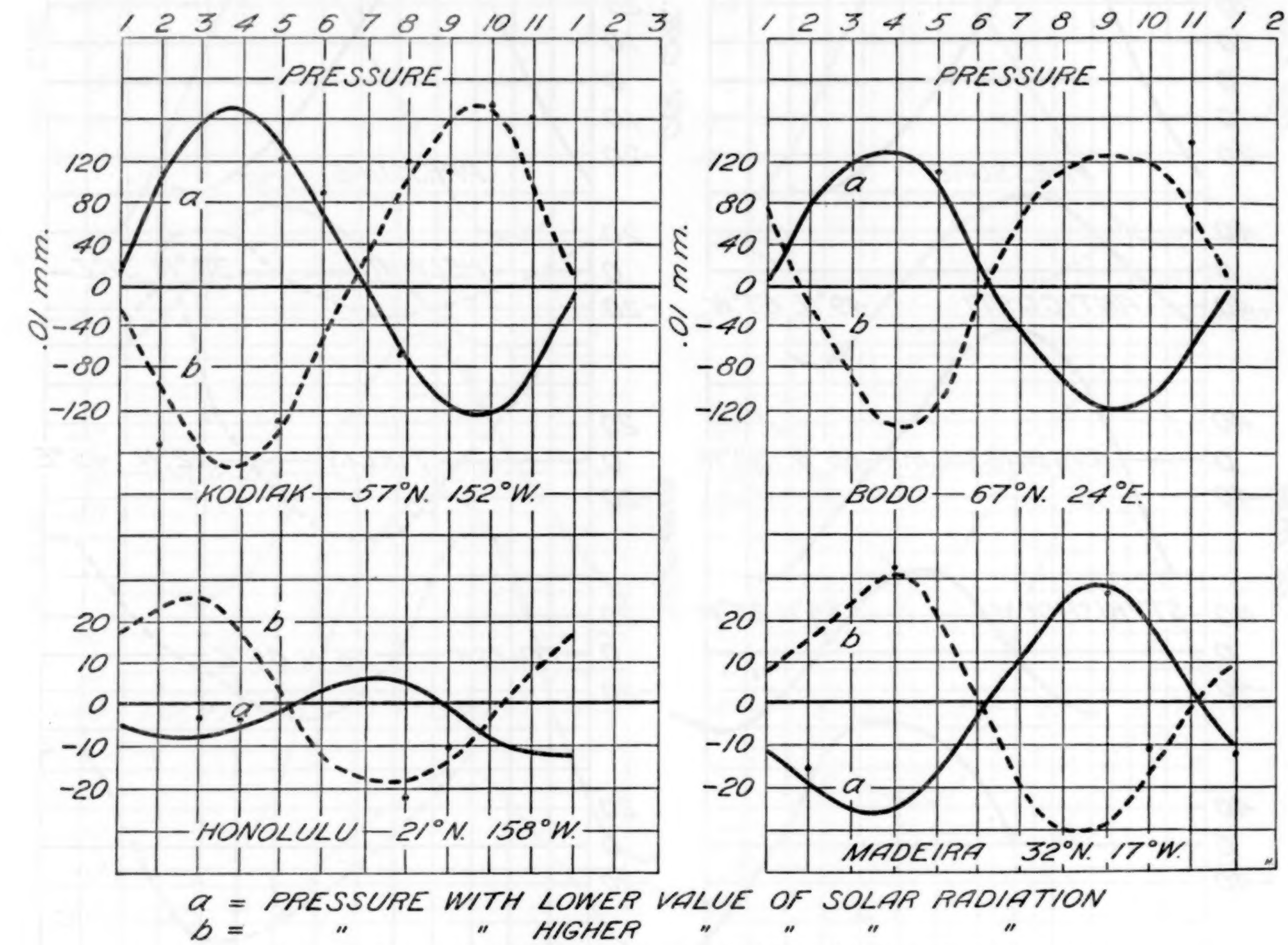

FIGURE 13.—Eleven-month period; inversions of pressure with changes in intensity of solar radiation.

When this process is carried beyond the sixth term and the successive weights are plotted, it is seen that the curve closely approximates to a cosine curve, which it may become when the summations are carried far enough. After six summations the process thus becomes equivalent to harmonic smoothing to which I was led by another process of reasoning.

More rapid smoothing may be obtained by adding more terms together; thus, one may add $a+b+c+d$ and then sum them by two in the next summation so that the formula becomes $a+2b+2c+2d+e$. Other combinations may be used, but all are intermediate between the first and second method described above.

[1] This part of the present paper is a copy of a paper filed with the Smithsonian Institution on Oct. 30, 1930, describing the process used by me in forecasting weather, except that it has been modified to accord with present practice.

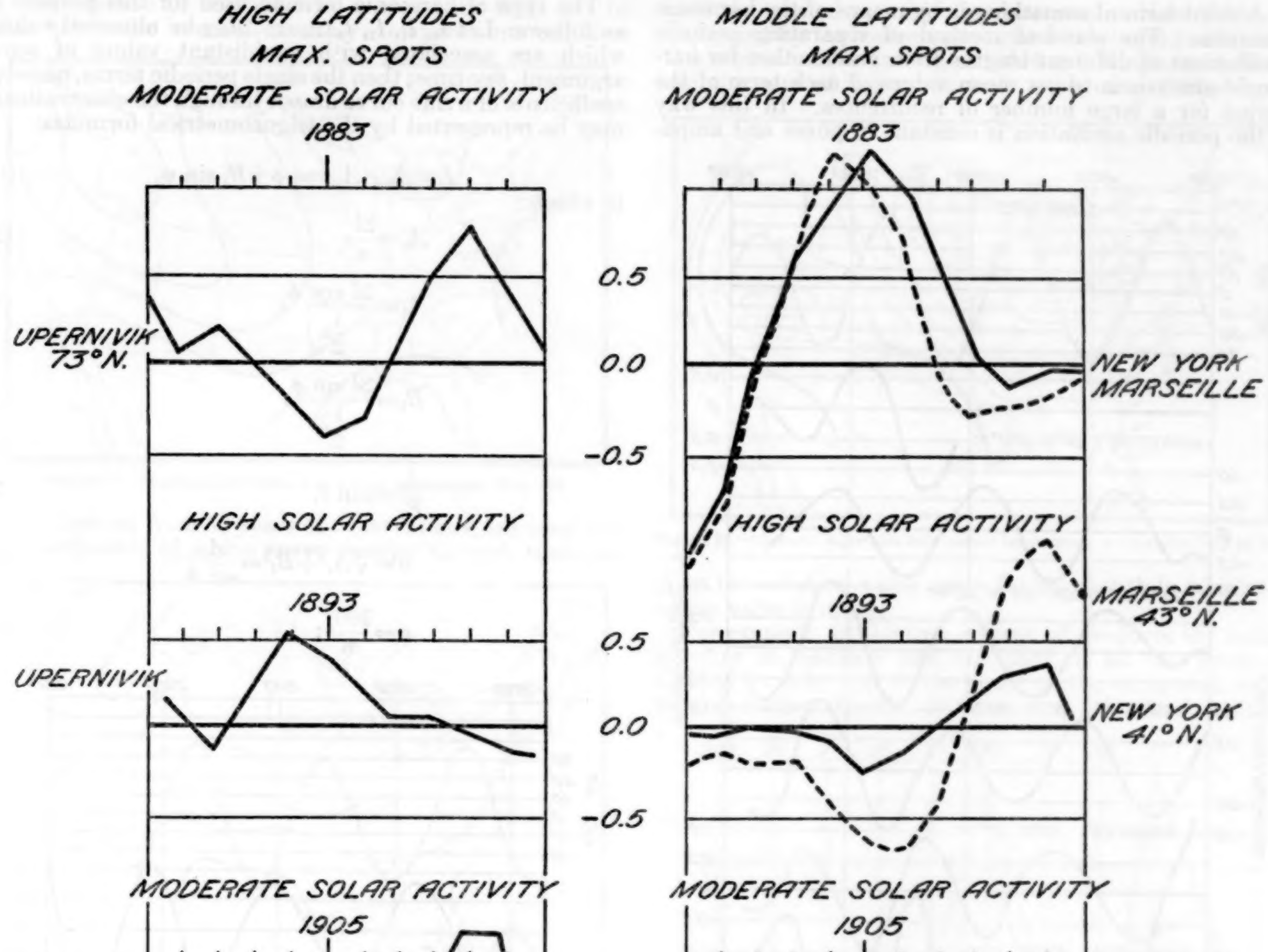

FIGURE 14.—Smoothed annual means of pressure (mm) during the sunspot period, northern hemisphere (*Smith. Misc. Coll.*, vol. 89, no. 15, p. 10).

A third form of smoothing is by means of the harmonic formulas. The classical method of separating periodic oscillations of different lengths from one another for harmonic analysis is to get mean values of each term of the period for a large number of recurrences. In this way if the periodic oscillation is constant in phase and amplitude, all periods of different length and all accidental variations are gradually eliminated by overlapping of positive and negative values. If, for example, the annual period of temperature is desired, the mean values for each month of the year for 50 or 100 years give a smooth curve when plotted, showing the annual period separated from irregularities or from any periodicity of other length.

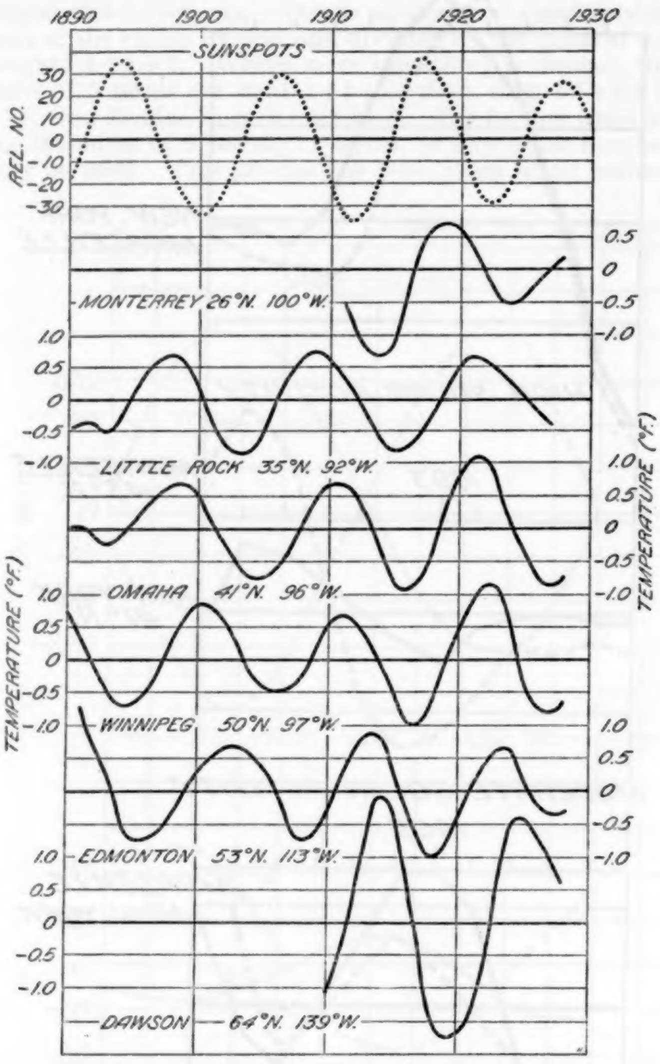

FIGURE 15.—Twelve-year harmons of sunspots and temperature (1).

If, however, a period varies somewhat in length and shows considerable variations in intensity, this method does not apply so well; and in the case of weather periods, which not only vary in length and intensity but show frequent reversals of phase this method of separating periods utterly fails. For this reason the use of the Schuster periodogram is of very questionable value in the search for meteorological periods. The periods cannot be represented in such a case by a set of sine and cosine functions which remain constant in value, but by computing sine and cosine functions for each individual period its oscillations can be followed to some extent and valuable information gained.

The type of harmonic formula used for this purpose is as follows: Let $l_0, l_1, l_2, l_3 \text{---------} l_{n-1}$ be observed values which are associated with equidistant values of some argument, say time; then the single periodic terms, namely, coefficients of a sine curve drawn through the observations, may be represented by the trigonometrical formulas:

$$L = A_0 + A_1 \cos \phi + B_1 \sin \phi, \tag{1}$$

in which

$$A_0 = \frac{\Sigma l}{n}, \tag{2}$$

$$A_1 = \frac{\Sigma l \cos \phi}{\frac{1}{2}n}, \tag{3}$$

$$B_1 = \frac{\Sigma l \sin \phi}{\frac{1}{2}n}, \tag{4}$$

$$\frac{A_1}{B_1} = \tan \theta, \tag{5}$$

$$a = \sqrt{A_1^2 + B_1^2} = \frac{A_1}{\sin \theta} \tag{6}$$

$$\phi = \frac{360°}{n}; \tag{7}$$

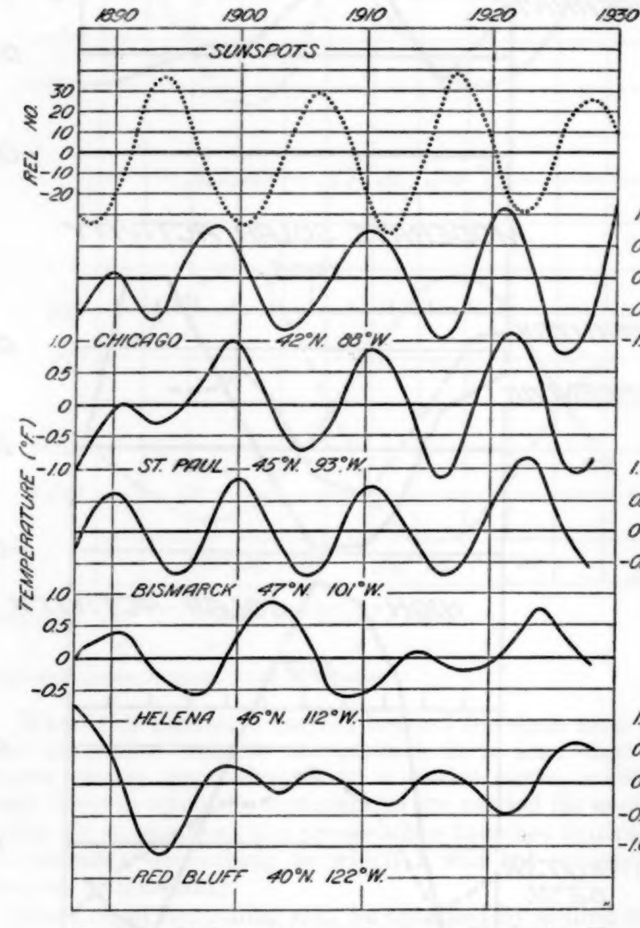

FIGURE 16.—Twelve-year harmons of sunspots and temperature (2).

where θ=angle of the epoch, namely, the angular distance from zero to the part of the sine curve at the beginning of the period, and a=amplitude, while n=number of terms used.

The method of computation is shown in table 1. In this table the normal monthly temperatures at New

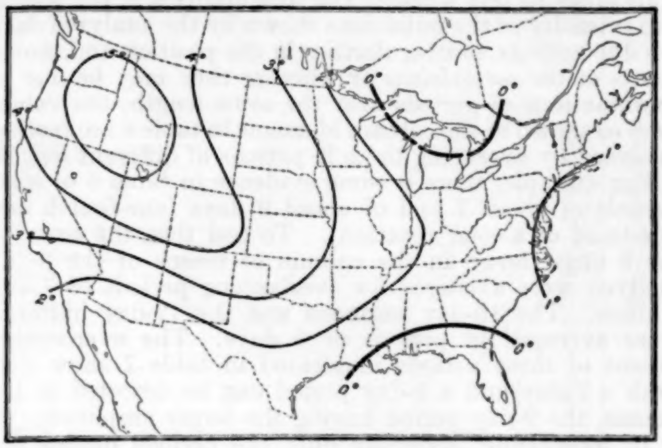

FIGURE 17.—Predicted departures from normal temperature, May 1936.

York, derived from 50 years of observations, are used and the coefficients of a sine curve passing through them are

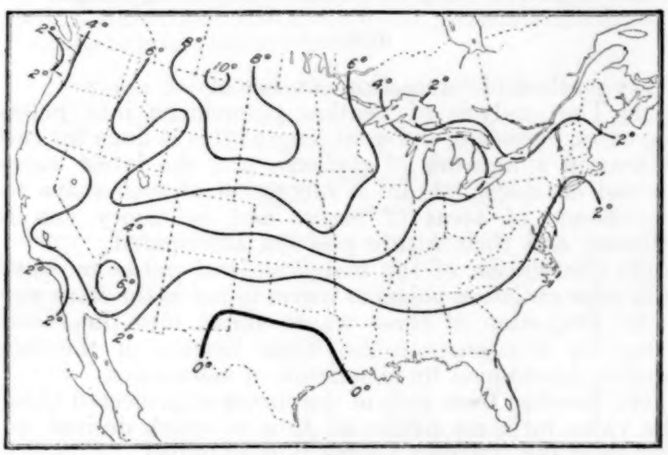

FIGURE 18.—Observed departures from normal temperature, May 1936.

computed. From these coefficients, monthly values are then computed and are given at the bottom of the table. It is seen that these differ very little from the observed

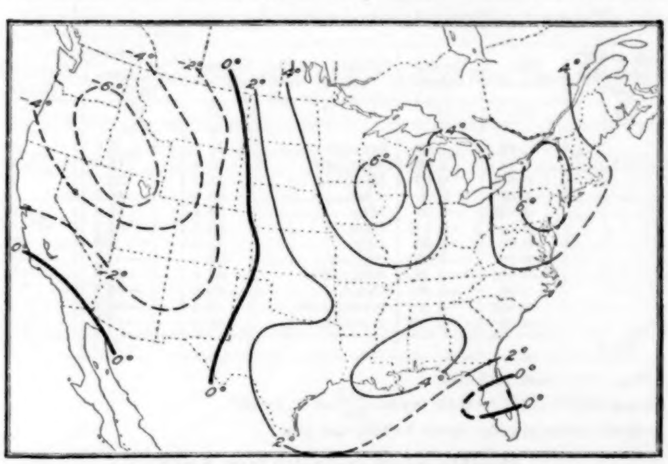

FIGURE 19.—Predicted departures from normal temperature, week ending July 14, 1936.

values, showing that these observed values follow very nearly a sine curve.

The computed values for each month may, however, be obtained in a different way as shown in table 2. In this table the normal monthly temperatures at New York are multiplied by the cosine values given in column 3 of table 1. The cosine values are slipped down 1 month at a time, and the sum of the products in each case divided by 6

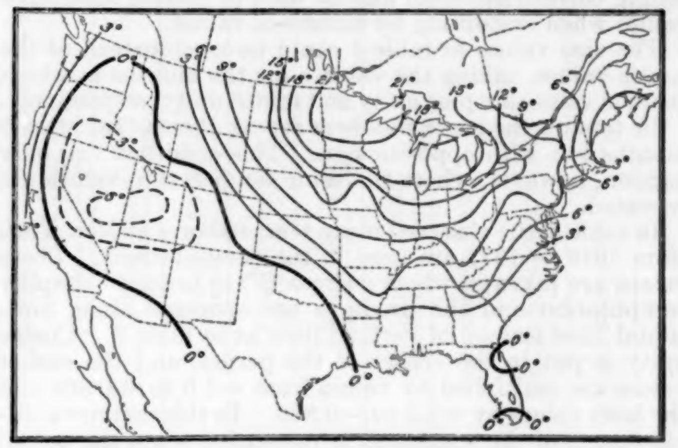

FIGURE 20.—Observed departures from normal temperature, week ending July 14, 1936.

gives the value on a sine curve for the month in which the cosine value is unity.

For example, in the first column of products the cosine is unity in January and the sum of all the products divided by 6 is -21.7, the same as the computed value in table 1 when $A_0=O$. In the second column of products

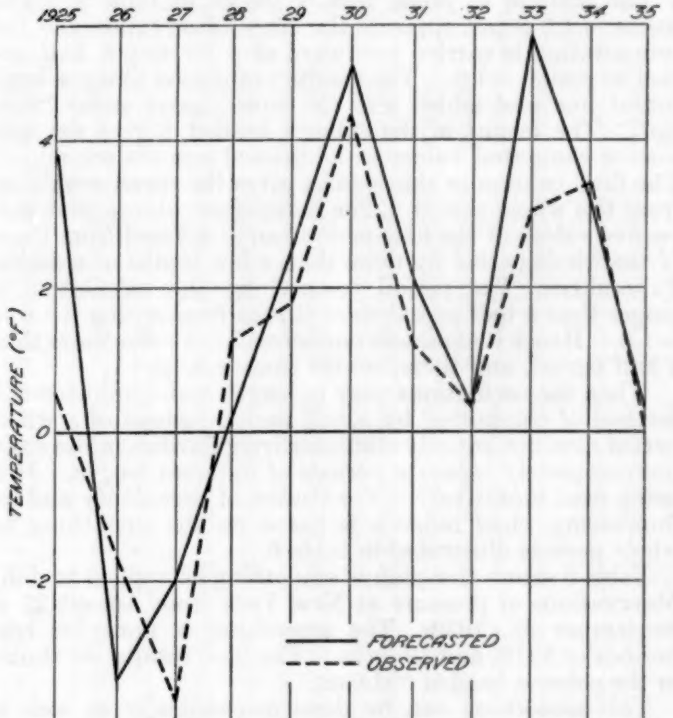

FIGURE 21.—Forecast of departures of June temperatures from normal, New Haven, Conn.

the cosine unity is placed in February, and the sine of the products divided by 6 is -20.7; and so on successively for each month. These are nearly identical with the computed values in table 1 when $A_0=O$. The small differences that exist are accounted for by the fact that the cosine factors were only taken to two or three decimals instead of to four or more. The successive values are thus equivalent to those of moving means except that the smoothing is done by harmonic terms instead of numerically.

This process in reality determines the best fit of a cosine curve with observed values, by the method of correlation. This fact may be seen by the example given in table 3. From this example it is evident that any machine for computing correlation could also be used in getting successive values when smoothing by harmonic values.

The sine values in table 1 could be used instead of the cosine values, taking the value a for the months in which the sine values are plus unity and minus unity, respectively.

In table 2 the same numbers repeat themselves after 6 months but with opposite sign. This condition can only happen, however, where the same temperature values are repeated.

In table 4, the observed mean temperatures at New York from 1918 to 1921 are used in the computations. These means are taken in whole degrees (F) in order to simplify computation and the products are arranged along horizontal lines instead of vertical lines as in table 3. Cosine unity is put in the center of the period, and the earlier values are multiplied by values from -1.0 to $+0.866$ and the later values by $+1.0$ to -0.866. In this manner a displacement of the maximum is prevented when the actual oscillation is longer or shorter than the trial period.

In the case of solar and weather periods where the period is changing amplitude and length or even inverting in phase, it is desirable to make the computations cover as short a period of time as possible and to bring the computed value as near the date of the latest observation as possible. This result can be approximated by computing the values for half a period instead of for the whole period.

The method of doing this is shown in table 5. The cosine $+1.0$ is put opposite the latest observation and the computation is carried backward step by step a half period to cosine -1.0. The results are placed along a horizontal line and added and the sum placed under "sum $\frac{1}{2}p$." The means in the column headed $\frac{1}{4}$ give the successive computed values as additional months are added. The final column in this exhibit gives the mean computed from the whole period. The comparison shows that successive values of the half period rarely differed from those of the whole period by more than a few tenths of a degree Fahrenheit. The period covered by the calculation is longer than a half period since it runs from cosine $+1.0$ to -1.0. Hence it embraces one term of full value more than a half period, and therefore the divisor is $\frac{1}{4}h+1$.

When the oscillations vary in length and amplitude this method of computing by a half period instead of a whole period does not entirely eliminate irregularities in the data, nor completely separate periods of different length. It is being used tentatively. For studies of periodicity and for forecasting, chief reliance is based on the smoothing by whole periods illustrated in table 6.

Table 6 shows this plan of smoothing as applied to daily observations of pressure at New York from August 23 to September 23, 1930. The smoothing is done for trial periods of 8, 10, and 12 days. The final results are shown in the column headed "Means."

This smoothing can be done mechanically as well as numerically. In the late spring of 1930 Maj. Lawrence Clayton, of the United States Army, then on leave, made a search, at my request, for mechanical methods of harmonic smoothing. He found that Vanevar Bush, of the Massachusetts Institute of Technology, had devised a machine, for computing correlations, called a photoelectric integraph which could be adapted to perform all of the various processes of smoothing. The machine was then in a crude form and I did not have the means to improve or modify it, so continued to smooth by a simplified process of numerical computations. This machine is now being improved by Bush and can no doubt greatly simplify the work of the various smoothing processes.

In order to test whether the irregularities in the length and intensity of the pulsations shown by the analyzed data are due entirely to irregularities in the position and movements of the *meiopleions* or whether they may be due to combinations of periods near the same length, the values such as shown in the column of means in table 6 are further analyzed by averaging them in periods of different length.

For example, there is some evidence in table 6 of solar periods of about 7 and of about 9 days (one-fourth and one-third of a solar rotation). To test this, the *harmons* for 8 days shown in the column of means of the 8-day analysis were averaged for overlapping periods of 7 and 9 days. The 10-day harmons and the 12-day harmons were averaged in periods of 9 days. The overlapping means of three periods illustrated in table 7 show that both a 7-day and a 9-day period can be detected in the means, the 9-day period having the larger amplitude.

In forecasting, generally only the periods having the larger amplitudes at any given time are used. In case the phase of the period does not invert frequently, as in the case of the solar periods, then overlapping means of 5 and 10 periods may be obtained advantageously.

SUMMARY

My method of forecasting consists of—

(1) The analysis of weather phenomena into pulses, waves, or periods of different length; this is done for each station in a network of stations, and the latest values plotted on maps. From a succession of such maps the movements of areas of excess and deficiency can be followed and their future position anticipated.

(2) Correlation of the meteorological pulses or waves with solar radiation pulses or waves found in the same way.

(3) Projection of these waves ahead into the future, using for this purpose the mean lengths of the solar periods determined by experience or calculation.

(4) Reading from each of the curves so projected ahead, the value for some particular time or epoch desired, and summing the different values thus obtained.

(5) The process described in (3) is done for a network of stations, the sums are plotted on maps and lines of equal value drawn. These maps then become a forecast for the area covered (see figs. 17 and 19).

TABLE 1.—*Example computation by harmonic formula*

Cycle of 360° divided into 12 parts	Sine values	Cosine values	Normal monthly temperatures, New York [1]		Temperatures— By sine values	Temperatures— By cosine values
(1)	(2)	(3)	(4)	(5)	(6)	(7)
				°F	°F.	°F.
0°	0.00	1.00	January	30.6	0.0	30.6
30°	0.50	0.866	February	30.5	15.3	26.4
60°	0.866	0.50	March	38.0	32.9	19.0
90°	1.00	0.00	April	48.5	48.5	0.0
120°	0.866	−0.50	May	59.4	51.4	−29.7
150°	0.50	−0.866	June	68.5	34.3	−59.3
180°	0.00	−1.00	July	73.5	0.0	−73.5
210°	−0.50	−0.866	August	72.1	−36.1	−62.4
240°	−0.866	−0.50	September	66.4	−57.5	−33.2
270°	−1.00	−0.00	October	55.8	−55.8	0.0
300°	−0.866	0.50	November	44.1	−38.2	22.1
330°	−0.50	0.866	December	34.3	−17.2	29.7
Sum					−22.4	−130.3

[1] Mean of 51 years, 1873–1923.

$a=\frac{1}{6}\sqrt{(22.4)^2+(130.3)^2}=22.04$; $\tan\theta=\frac{130.3}{22.4}=5.81$; $\theta=260°$.

θ=epoch; a=amplitude; A_0=51.8=Mean for year.

Monthly values computed from θ and a

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
For A_0=0	−21.7	−20.7	−14.1	−3.8	7.6	17.0	21.7	20.7	14.1	3.8	−7.6	−17.0
For A_0=51.8	30.1	31.1	37.7	48.0	59.4	68.8	73.5	72.5	65.9	55.6	44.2	34.8

TABLE 2.—*Temperatures multiplied by cosine values*

	Normal monthly tempera-tures at New York [1]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
January	30.6	30.6											
February	30.5	26.4	30.5										
March	38.0	19.0	32.9	38.0									
April	48.5	0.0	24.3	42.0	48.5								
May	59.4	−29.7	0.0	29.7	51.4	59.4							
June	68.5	−59.3	−34.3	0.0	34.3	59.3	68.5						
July	73.5	−73.5	−63.7	−36.8	0.0	36.8	63.7	73.5					
August	72.1	−62.4	−72.1	−62.4	−36.1	0.0	36.1	62.4	72.1				
September	66.4	−33.2	−57.5	−66.4	−57.5	−33.2	0.0	33.2	57.6	66.4			
October	55.8	0.0	−27.9	−48.3	−55.8	−48.3	−27.9	0.0	27.9	48.3	55.8		
November	44.1	22.1	0.0	−22.1	−38.2	−44.1	−38.2	−22.1	0.0	22.1	38.1	44.1	
December	34.3	29.7	17.2	0.0	−17.2	−29.7	−34.3	−29.7	−17.2	0.0	17.2	29.7	34.3
January	30.6		26.5	15.3	0.0	−15.3	−26.5	−30.6	−26.5	−15.3	0.0	15.3	26.5
February	30.5			26.4	15.3	0.0	−15.3	−26.4	−30.5	−26.4	−15.3	0.0	15.3
March	38.0				32.9	19.0	0.0	−19.0	−32.9	−38.0	−32.9	−19.0	0.0
April	48.5					42.0	24.3	0.0	−24.3	−42.0	−48.5	−42.0	−24.3
May	59.4						51.4	29.7	0.0	−29.7	−51.4	−59.4	−51.4
June	68.5							59.3	34.3	0.0	−34.3	−59.3	−68.5
July	73.5								63.7	36.8	0.0	−36.8	−63.7
August	72.1									62.4	36.1	0.0	−36.1
September	66.4										57.5	33.2	0.0
October	55.8											48.3	27.9
November	44.1												38.2
December	34.3												
Sums		−130.3	−124.3	−84.6	−22.4	45.9	101.8	130.3	124.2	84.6	22.3	−45.9	−101.8
Means, ⅙		−21.7	−20.7	−14.1	−3.7	7.6	17.0	21.7	20.7	14.1	3.7	−7.6	−17.0
Observed		−21.2	−21.3	−13.8	−3.3	7.6	16.7	21.7	20.3	14.6	4.0	−7.7	−17.5

[1] Averages of 51 years, 1873–1923.

TABLE 3.—*Harmonic terms computed by correlations*

(1) Month	(2) x=cosine values	(3) y=temper-ature de-partures	(4) xy=prod-uct	(5) x^2	(6) y^2
July	1.00	21.7	21.7	1.00	471
August	.866	20.3	17.6	.75	412
September	.50	14.6	7.3	.25	213
October	.00	4.0	.0	.00	16
November	−.50	−7.7	3.8	.25	136
December	−.866	−17.5	15.1	.75	306
January	−1.00	−21.2	21.2	1.00	449
February	−.866	−21.3	18.4	.75	454
March	−.50	−13.8	6.9	.25	190
April	.00	−3.3	.0	.00	44
May	.50	7.6	3.8	.25	134
June	.866	16.7	14.5	.75	279
Sums	.00	.0	130.3	6.00	3104

$$\text{Correlation coefficient } r=\frac{\Sigma xy}{\sqrt{\Sigma x^2.\Sigma y^2}}=\frac{130.3}{\sqrt{6\times 3104}}=\frac{130.3}{136.8}=0.95$$

$$a=\frac{\Sigma xy}{\Sigma x^2}=\frac{130.3}{6}=21.7$$

NOTE.—a=ratio of the observed values to a cosine series having plus unity in July and minus unity in January.

TABLE 4.—*Monthly mean temperatures at New York smoothed harmonically (1)*

Angle / Cosine	*	180° −1.0	210° −0.866	240° −0.5	270° 0	300° 0.5	330° 0.866	0° 1.0	30° 0.866	60° 0.5	90° 0	120° −0.5	150° −0.866	Sum	⅙
1918															
Jan.	21														
Feb.	29														
Mar.	41														
Apr.	49														
May	63														
June	66														
July	72	−21	−25	−21	0	32	57	72	64	31	0	−23	−33	133	*22.2*

TABLE 4.—*Monthly mean temperatures at New York smoothed harmonically (1)*—Continued

Angle / Cosine		180° −1.0	210° −0.866	240° −0.5	270° 0	300° 0.5	330° 0.866	0° 1.0	30° 0.866	60° 0.5	90° 0	120° −0.5	150° −0.866	Sum	⅙
1918															
Aug.	74	−29	−35	−25	0	33	62	74	53	29	0	−20	−30	112	*18.7*
Sept.	62	−41	−42	−32	0	36	64	62	51	23	0	−18	−30	73	*12.2*
Oct.	58	−49	−54	−33	0	37	53	58	30	20	0	−18	−36	17	*2.9*
Nov.	46	−63	−57	−36	0	31	51	46	33	18	0	−21	−41	−39	*−6.5*
Dec.	39	−66	−62	−37	0	29	39	39	30	18	0	−24	−51	−85	*−14.2*
1919															
Jan.	35	−72	−64	−31	0	23	33	35	30	21	0	−30	−59	−114	*−19.0*
Feb.	35	−74	−53	−29	0	20	30	35	36	24	0	−35	−63	−109	*−18.2*
Mar.	42	−62	−50	−23	0	18	30	42	41	30	0	−37	−60	−71	*−11.8*
Apr.	48	−58	−39	−20	0	18	36	48	51	35	0	−35	−57	−21	*−3.5*
May	60	−46	−33	−18	0	21	41	60	59	37	0	−33	−50	38	*6.3*
June	69	−39	−30	−18	0	24	51	69	63	35	0	−29	−38	88	*14.7*
July	73	−35	−30	−21	0	30	59	73	60	33	0	−22	−26	121	*20.3*
Aug.	70	−35	−36	−24	0	35	63	70	57	29	0	−15	−21	123	*20.5*
Sept.	66	−42	−41	−30	0	37	60	66	50	22	0	−12	−25	85	*14.2*
Oct.	58	−48	−51	−35	0	35	57	58	38	15	0	−15	−34	20	*3.3*
Nov.	44	−60	−59	−37	0	33	50	44	26	12	0	−20	−40	−51	*−8.5*
Dec.	30	−69	−63	−35	0	29	38	30	21	15	0	−24	−49	−107	*−17.5*
1920															
Jan.	24	−73	−60	−33	0	22	26	24	25	20	0	−29	−58	−136	*−22.7*
Feb.	29	−70	−57	−29	0	15	21	29	34	24	0	−34	−63	−130	*−21.7*
Mar.	40	−66	−50	−22	0	12	25	40	40	29	0	−36	−63	−91	*−15.2*
Apr.	47	−58	−38	−15	0	15	34	47	49	34	0	−36	−58	−26	*−4.3*
May	57	−44	−26	−12	0	20	40	57	58	36	0	−34	−51	44	*7.3*
June	67	−30	−21	−15	0	24	49	67	63	36	0	−30	−39	105	*17.5*
July	72	−24	−25	−20	0	29	58	72	63	34	0	−22	−33	132	*22.0*
Aug.	72	−29	−35	−24	0	34	63	72	58	30	0	−19	−28	122	*20.3*
Sept.	67	−40	−40	−29	0	36	63	67	51	22	0	−17	−30	83	*13.8*
Oct.	60	−47	−49	−34	0	36	58	60	38	19	0	−18	−41	22	*3.7*
Nov.	44	−57	−58	−36	0	34	51	44	33	17	0	−24	−47	−43	*−7.2*
Dec.	38	−67	−63	−36	0	30	38	38	28	18	0	−28	−52	−94	*−15.7*
1921															
Jan.	33	−72	−63	−34	0	22	33	33	30	24	0	−30	−60	−117	*−19.5*
Feb.	35	−72	−58	−30	0	19	28	35	41	28	0	−35	−65	−109	*−18.2*
Mar.	48	−67	−51	−22	0	17	30	48	47	30	0	−38			
Apr.	55	−60	−38	−19	0	18	41	55	52	35	0				
May	60	−44	−33	−17	0	24	47	60	60	38	0				
June	70	−38	−29	−18	0	28	52	70	65						
July	76	−33	−30	−24	0	30	60	76							

TABLE 5.—*Monthly mean temperatures at New York smoothed harmonically (2)*

Angle	0°	30°	60°	90°	120°	150°	180°	Sum 1/2 period	Mean 1/4	Sum less column 0°	Sum whole period [1]	Mean 1/6
Cosine	1.0	0.866	0.5	0	−0.5	−0.866	−1.0					
1918												
Jan	21											
Feb	29											
Mar	41											
Apr	49											
May	63											
June	66											
July	72	57	32	0	−21	−25	−21	94	*23.5*	22	133	*22.2*
Aug	74	62	33	0	−25	−35	−29	80	*20.0*	6	112	*18.7*
Sept	62	64	36	0	−32	−42	−41	47	*11.8*	−15	72	*12.0*
Oct	58	53	37	0	−33	−54	−49	12	*3.0*	−46	17	*2.9*
Nov	46	50	31	0	−36	−57	−63	−29	*−7.2*	−75	−40	*−6.7*
Dec	39	39	29	0	−37	−62	−66	−58	*−14.5*	−97	−85	*−14.2*
1919												
Jan	35	33	23	0	−31	−64	−72	−76	*−19.0*	−111	−114	*−19.0*
Feb	35	30	20	0	−29	−53	−74	−71	*−17.8*	−106	−109	*−18.2*
Mar	42	30	18	0	−23	−50	−62	−45	*−11.3*	−87	−71	*−11.8*
Apr	48	36	18	0	−20	−39	−58	−15	*−3.8*	−63	−21	*−3.5*
May	60	41	21	0	−18	−33	−46	25	*6.3*	−35	38	*6.3*
June	69	51	24	0	−18	−30	−39	57	*14.3*	−12	88	*14.7*
July	73	59	30	0	−21	−30	−35	76	*19.0*	3	121	*20.2*
Aug	70	63	35	0	−24	−36	−35	73	*18.3*	3	123	*20.5*
Sept	66	60	37	0	−30	−41	−42	50	*12.5*	−16	85	*14.2*

[1] Add sum in preceding column to sum 6 months later with sign reversed.

TABLE 5.—*Monthly mean temperatures at New York smoothed harmonically (2)*—Continued

Angle	0°	30°	60°	90°	120°	150°	180°	Sum 1/2 period	Mean 1/4	Sum less column 0°	Sum whole period [1]	Mean 1/6
Cosine	1.0	0.866	0.5	0	−0.5	−0.866	−1.0					
1919												
Oct	58	57	35	0	−35	−51	−48	16	*4.0*	−42	20	*3.3*
Nov	44	50	33	0	−37	−59	−60	−29	*−7.3*	−73	−51	*−8.5*
Dec	30	38	29	0	−35	−63	−69	−70	*−17.5*	−100	−107	*−17.5*
1920												
Jan	24	26	22	0	−33	−60	−73	−94	*−23.5*	−118	−136	*−22.7*
Feb	29	21	15	0	−29	−57	−70	−91	*−22.8*	−120	−129	*−21.7*
Mar	40	25	12	0	−22	−50	−66	−61	*−15.2*	−101	−91	*−15.2*
Apr	47	34	15	0	−15	−38	−58	−15	*−3.8*	−62	−26	*−4.3*
May	57	40	20	0	−12	−26	−44	35	*8.7*	−22	44	*7.3*
June	67	49	24	0	−15	−21	−30	74	*18.5*	7	105	*17.5*
July	72	58	29	0	−20	−25	−24	90	*22.5*	18	132	*22.0*
Aug	72	63	34	0	−24	−35	−29	81	*20.2*	9	122	*20.3*
Sept	67	63	36	0	−29	−40	−40	57	*14.2*	−10	83	*13.8*
Oct	60	58	36	0	−34	−49	−47	24	*6.0*	−36	22	*3.7*
Nov	44	51	34	0	−36	−58	−57	−22	*−5.5*	−66	−43	*−7.2*
Dec	38	38	30	0	−36	−62	−67	−59	*−14.7*	−97	−93	*−15.7*
1921												
Jan	33	33	22	0	−34	−62	−72	−80	*−20.0*	−113	−117	*−19.5*
Feb	35	28	19	0	−30	−58	−72	−78	*−19.5*	−113		
Mar	48	30	17	0	−22	−51	−67	−45	*−11.2*	−93		
Apr	55	41	18	0	−19	−38	−60	−3	*−0.8*	−58		
May	60	47	24	0	−17	−33	−44	37	*9.3*	−23		
June	70	52	28	0	−18	−28	−38	66	*16.5*	−4		
July	76	60	30	0	−24	−30	−33	79	*19.8*	4		

TABLE 6.—*8 a. m. pressures at New York analyzed in periods of 8, 10, and 12 days*

	Observed pressure 29.00 in.	8-day analysis							10-day analysis								12-day analysis								
		1.0	0.7	0	−0.7	Sum	Difference [1] 4	1/4	1.0	0.8	0.3	0.3	−0.8	Sum	Difference [1] 5	1/5	1.0	0.866	0.5	0	−0.5	−0.866	Sum	Difference 6	1/6
1930	+																								
Aug. 13	1.34	134							134								134								
14	1.12	112							112								112								
15	.96	96							96								96								
16	.88	88							88								88								
17	.98	98	62	0	−78	82	−49	[2]−12	98								96								
18	.82	82	69	0	−67	84	−34	−9	82	78	26	−29	−90	67	−24	−5	82								
19	.94	94	57	0	−62	89	11	3	94	68	29	−26	−77	88	7	1	94	71	49	0	−48	−97	69	−28	[2]−5
20	1.08	108	66	0	−69	105	23	6	108	75	25	−29	−70	109	−8	−2	108	83	41	0	−44	−82	106	−8	−1
21	1.12	112	76	0	−57	131	18	5	112	86	28	−25	−78	123	−4	−1	112	93	47	0	−49	−75	128	1	0
22	1.06	106	78	0	−66	118	−19	−5	106	90	32	−28	−68	132	−2	0	106	97	54	0	−41	−83	133	4	3
23	.80	80	74	0	−76	78	−31	[2]−8	80	85	33	−32	−75	91	−12	−2	80	92	56	0	−47	−71	110	20	1
24	1.04	104	56	0	−78	82	−14	−4	104	64	32	−33	−86	81	−2	0	104	69	53	0	−54	−83	89	6	1
25	1.16	116	71	0	−74	113	22	6	116	83	24	−32	−90	101	10	2	116	90	40	0	−56	−93	97	−20	−3
26	1.12	112	81	0	−56	137	38	10	112	93	31	−24	−85	127	1	0	112	100	52	0	−53	−97	114	−38	[2]−6
27	1.04	104	78	0	−73	109	−19	−5	104	90	35	−31	−64	134	−9	−2	104	97	58	0	−40	−92	127	−27	−5
28	1.04	104	73	0	−81	96	−59	[2]−15	104	83	34	−35	−83	103	−47	−9	104	90	56	0	−52	−69	129	7	1
29	.96	96	73	0	−78	91	−42	−11	96	83	31	−34	−93	83	−19	−4	96	90	52	0	−58	−90	90	−5	−1
30	1.04	104	67	0	−73	98	16	4	104	77	31	−31	−90	91	13	3	104	83	52	0	−56	−100	83	0	0
31	1.28	128	73	0	−73	128	44	11	128	83	29	−31	−83	126	32	6	128	90	48	0	−52	−97	117	34	6
Sept. 1	1.32	132	90	0	−67	155	41	10	132	102	31	−39	−83	143	37	7	132	110	52	0	−52	−90	152	58	9
2	1.14	114	92	0	−73	133	18	5	114	106	38	−31	−77	150	47	9	114	114	64	0	−48	−90	154	64	11
3	.92	92	80	0	−90	82	−7	[2]−2	92	91	40	−38	−83	102	28	6	92	99	66	0	−52	−83	122	32	5
4	1.12	112	64	0	−92	84	4	1	112	74	34	−40	−102	78	−19	−4	112	80	57	0	−64	−90	95	−16	−3
5	1.16	116	78	0	−80	114	3	1	116	90	28	−34	−106	94	−34	−7	116	97	46	0	−66	−110	83	−54	−9
6	.98	98	81	0	−64	115	−11	−3	98	93	34	−28	−91	106	−38	−8	98	100	56	0	−57	−114	83	−44	−7
7	.98	98	69	0	−79	89	−41	−10	98	78	35	−34	−74	103	−15	−3	98	85	58	0	−46	−99	96	−4	−1

[1] Differences from sums half a period later.

[2] Minima.

TABLE 7.—*Averaging harmons by solar periods*

	8-day harmon of pressure at New York													
7-day period	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1930								Means of 3						
Aug. 18	−9	3	6	5	−5	−8	−4							
Aug. 25	6	10	−5	−15	−11	4	11	2	*6*	0	−3	[1]−5	−2	−1
Sept. 1	10	5	−2	1	1	−3	−10	4	7	2	0	[1]−2	0	−3
Sept. 8	−3	7	13	13	3	−1	−11	−3	0	3	7	4		
Sept. 15	−14	−11	−2	6	7									
etc.														

9-day period	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1930										Means of 3								
Aug. 18	[1]−9	3	6	5	−5	−8	−4	6	10									
Aug. 27	−5	[1]−15	−11	4	*11*	10	5	−2	1	−4	[1]−5	−5	2	4	*5*	4	2	3
Sept. 5	1	−3	[1]−10	−3	7	*13*	13	3	−1	−5	[1]−11	−11	0	8	*10*			
Sept. 14	−11	[1]−14	−11	−2	6	7												
etc.																		

	10-day harmon of pressure at New York																	
9-day period	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
1930										Means of 3								
Aug. 18	[1]−5	2	2	−1	0	−2	0	*2*	0									
Aug. 27	0	[1]−9	−4	3	6	5	*11*	6	−4	[1]−5	−4	−2	0	4	5	*7*	5	−3
Sept. 5	[1]−9	−6	−5	−2	5	*12*	11	7	−4	−7	[1]−10	−6	−1	3				
Sept. 14	−12	[1]−14	−9	−3	−1													
etc.																		

[1] Minima.

CORRECTIONS TO ATMOSPHERIC TURBIDITY AND WATER VAPOR VALUES AS COMPUTED FROM SOLAR RADIATION INTENSITY MEASUREMENTS AT THE BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY DURING 1936

By HERBERT H. KIMBALL

[Research Associate, Harvard University, December 1936]

In August 1936, in response to a notice of the meeting of the Commission on Solar Radiation of the International Geodetic and Geophysical Union in Oxford, England, just prior to the meetings of the Union in Edinburgh, Scotland, in September, I sent my regrets that it would be impossible for me to attend these meetings.

At the same time I called attention to the fact that while many excellent measurements of the intensity of the total radiation, and of the radiation transmitted by standard color screens, had been received by me from a goodly number of stations, but few values of β, the coefficient of atmospheric turbidity, or of w, the precipitable water-vapor held in suspension in the atmosphere, had yet reached me from any foreign stations. Neither could I locate them in any library to which I had access.

In reply to my letter, Dr. Angström referred me to a paper by Von O. Hoelper, Aachen, Germany, published in the *Deutschen Meteorologischen Jahrbuch* for 1933. Hoelper's method of computing values of β and w differs from that followed in the United States, but it is believed that the two methods can be brought into accord. Already it is apparent that the American method is capable of improvement; and there are a few points in connection with the European method about which questions arise in my mind. In any case, the advantage that arises from international cooperation in this effort to study the characteristics of the different air masses that pass over us, some from Arctic regions, some from tropical oceanic regions, and some after marked changes have occurred as they passed over great land masses before reaching the points of observation, is a challenge to us to take advantage of all possible assistance, such as comes from an exchange of ideas in regard to difficulties encountered as the work progresses.

In the United States the atmospheric turbidity for dry air is determined from the differences in intensity of the screened readings (I_y-I_r); (see MO. WEA. REV., March 1933, p. 82, fig. 4). With this turbidity value, the intensity for dry air in the total spectrum, I_m, may be obtained by entering Figure 2 of the same REVIEW, page 81, with the value of the turbidity factor, β, just found, and with the same air mass as before. Then subtract from this intensity the intensity I_m as measured at this same time; the remainder gives the absorption of radiation by the water-vapor present in the atmosphere above the place of observation, expressed in mm of water that would be obtained if all the water-vapor in the path of the beam were precipitated. Dividing by the square root of the length of the path, m, we obtain the depth of water in mm that would be obtained if all the water in a vertical path of unit cross section above the place of observation were precipitated.

It was found that the transmission of the two color screens increases considerably with decrease in temperature; and the changes for each screen are given in table 3, page 4, MONTHLY WEATHER REVIEW, January 1936.

These changes in the value of the transmission of the screens with temperature are of minor importance, but I was greatly shocked when I discovered that the mean of the values derived from I_y-I, and from I_m-I_y had been employed to determine the value of β for dry air. I very much regret this error, for which I assume the full responsibility.

Our values for September were at once recomputed, all values of β being derived from I_y-I_r, but the work could not be completed in time to include the results in the September REVIEW. The October values were then derived in the same way, but I was unable to prepare the present explanatory statement to accompany them.

In the meantime, I have received a letter from Dr. Feussner, of the Potsdam, Germany, Observatory, in which he suggests still further changes in the method of computing β and w.

Briefly, from I_m, the total radiation intensity, plus F, the depletion by moisture computed by the so-called equation of Fowle (but which Fowle repudiates; it is an equation proposed long ago by Hann as an approximate method), the intensity that would have been observed had the air been dry is obtained. Hoelper also suggests that his curves published in the *Deutschen Meteorologischen Jahrbuch* for 1933 be used in place of those published in the MONTHLY WEATHER REVIEW paper above cited.

I believe that it may be possible to use Hoelper's curves, thereby bringing about uniformity in reduction of observations, both in the United States and Europe. I do not believe, however, that Fowle's equation, referred to above, should be employed in determining the radiation that would have been obtained through dry air. This question will be taken up with the Smithsonian Institution without delay.

NOTES AND REVIEWS

J. Namias, Introduction to the Study of Air Mass Analysis (Review).—The American Meteorological Society has published, as its June–July 1936 *Bulletin*, an 84-page booklet embodying a third edition of Jerome Namias' Introduction to the Study of Air Mass Analysis and an abbreviated revision of H. C. Willett's Characteristic Properties of North American Air Masses. Namias has endeavored to answer the many questions that form in the mind of the beginner, and to provide the foundation necessary for the study of more advanced papers.

Stability and lapse-rates are the subjects of the first article. A concise table at the end of the discussion shows just what atmospheric conditions must obtain for each of the various types of equilibrium to exist.

The conservative properties of air masses next receive attention; and air masses themselves, temperatures (equivalent, potential, and equivalent-potential), lapse-rates, humidity (vapor pressure, relative humidity, absolute humidity, and specific humidity), condensation forms, visibility, and wind direction and velocity are defined and discussed. Definite clues are given which are helpful in identifying various types of air masses by means of these properties.

Following this there is an article on the plotting of the Rossby Diagram, giving in detail the meaning and derivation of the various scales appearing on the chart.

The interpretation of the Rossby Diagram follows; and the method of determining the type of air mass from the general type of the characteristic curve is given, to-

gether with the changes these curves undergo as the more common atmospheric processes, such as vertical displacement, occur. Definite statements are given as to how the slope of the curve indicates the stability of the layer in question; e. g., "If the equivalent-potential temperature increases with elevation, the state is one of stability with respect to dry or saturated air, and no adiabatic process performed upon the layer will render it unstable."

Articles follow on frontal structure, one on warm fronts and another on cold fronts. Diagrams show cross-sections of the fronts, and the distribution of the meteorological elements in their neighborhood.

Cyclonic structure receives consideration in the succeeding article; and with the aid of diagrams, Namias explains the formation and appearance of various fronts and frontal systems. Included in this article is a table giving the average changes in pressure, temperature, relative humidity, specific humidity, clouds, precipitation, visibility, and wind which occur with the passage of warm, cold, or occluded fronts.

Tephigrams are taken up in the next article, and the principles of this type of chart explained and discussed.

Four general types of thunderstorms, i. e., air-mass, frontal, orographic, and those occurring in horizontally converging air currents, are considered in the last article; the various aspects and characteristics of each are discussed, together with the relation of the tephigram, particularly as regards forecasting, to each.

An appendix presents Willett's "Characteristic Properties of North American Air Masses." It includes sections on the general classification of air masses, and on the significance of the properties of the principal air mass types in summer and winter. This discussion includes the results of recent investigations of the tropical air masses, especially the so-called Ts or S air.

A large selection of references for further reading in English, and a few in foreign languages, are given. Also, there is a glossary of technical terms used in the paper.—*Verne D. Steves.*

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[RICHMOND T. ZOCH, *in Charge of Library*]

By AMY D. PUTNAM

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

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SOLAR OBSERVATIONS

SOLAR RADIATION OBSERVATIONS DURING NOVEMBER 1936

By IRVING F. HAND, *Assistant in Solar Radiation Investigations*

For a description of instruments employed and their exposures, the reader is referred to the January 1935 REVIEW, page 24.

Table 1 shows that solar radiation intensities averaged below normal for November at Washington and Madison, and close to normal at Lincoln. The effect of city smoke and haze as a depletor of solar radiation is markedly shown by observations taken at Lincoln on the 20th. In the afternoon at air mass 2, the value was but slightly below normal; and less than an hour later, or at air mass 3, the value was less than 50 percent of the normal for that air mass. Between the times of taking these two observations, the wind had shifted, bringing city smoke and haze over the station. As smoke and haze diminish the amount of short wave-length radiation, or the so-called health-giving radiation, received at the earth's surface, much more than they do the longer wave lengths, it is reasonable to conclude that under such extreme conditions the amount of ultra-violet reaching the earth is tremendously reduced. As a further example, the radiation receipt at air mass 4 was 23 percent greater than at air mass 3.5 owing to a temporary clearing of the atmosphere. Somewhat similar conditions prevailed in the late afternoon of the same day at Madison.

Table 2 shows a deficiency in the total solar and sky radiation received on a horizontal surface at Washington, Miami, Fairbanks, and Riverside, and an excess at all other stations.

Polarization observations taken at Washington on 71 days give a mean of 55 percent with a maximum of 58 percent on the 14th. At Madison, observations made on 7 days give a mean of 60 percent with a maximum of 71 percent on the 4th. All of these values are below the corresponding normals for the month.

TABLE 1.—*Solar radiation intensities during November 1936*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance										
	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm*
Nov. 9	5.56	0.45	0.61	0.80	0.98						6.27
Nov. 10	8.48	.52	.70	.85							5.56
Nov. 11	11.38			1.02	1.19						4.75

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during November 1936*—Con.

WASHINGTON, D. C.—Continued

Date	Sun's zenith distance										
	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm*
Nov. 13	14.10				.94		0.99				5.36
Nov. 14	6.76			.83	1.23						5.79
Nov. 19	5.56				1.45		1.39	1.23			3.45
Nov. 23	3.00				1.12		1.09				2.36
Nov. 27	4.37			.72							1.45
Means		(.48)	(.66)	.84	1.15		1.16	(1.23)			
Departures		−.27	−.21	−.17	−.04		−.02	+.23			

MADISON, WIS.

Date	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Nov. 4	2.36		0.94		1.47						1.78
Nov. 10	2.74		.92	1.11	1.35			1.10			3.30
Nov. 12	4.95						1.36	.99			4.95
Nov. 14	5.16				1.43						5.36
Nov. 16	2.26	1.04	1.12	1.31	1.43		1.38	1.08			2.62
Nov. 17	3.63	.84	.94	1.06	1.33			1.29			4.95
Nov. 20	4.57		.80					.93	0.40	0.24	5.16
Nov. 30	1.32	.75	.84	1.06							2.26
Means		.88	.93	1.14	1.40		(1.37)	1.07	(.40)	(.24)	
Departures		−.09	−.08	−.10	−.10		+.04	−.05	−.44		

LINCOLN, NEBR.

Date	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Nov. 3	1.27	1.09	1.18	1.35	1.51		1.51	1.31	1.18	1.08	1.78
Nov. 5	2.74	.96	1.06					1.24	1.07	.97	3.00
Nov. 9	3.30	.98	1.14	1.28	1.41					1.04	3.45
Nov. 10	3.15	1.00	1.08	1.24	1.44		1.41	1.21	1.06	.96	3.45
Nov. 11	3.45	.86	.99	1.16							3.45
Nov. 12	3.15							1.20	1.06	.95	4.17
Nov. 13	3.15		1.04	1.24							2.87
Nov. 17	4.37	.98	1.12	1.26	1.39		1.39	1.20	1.05	.96	4.95
Nov. 19	4.95				1.34		1.37				4.95
Nov. 20	3.63	.88		1.13	1.35		1.16	.58	.54	.38	4.57
Nov. 21	2.49	.97	1.11	1.26	1.48						2.16
Nov. 25	1.88	1.20									2.36
Nov. 27	2.87							1.11	.97	.92	3.81
Nov. 28	3.00	1.03	1.15	1.30	1.50						3.81
Nov. 30	2.36	.99	1.12	1.23	1.39		1.35	1.09			3.00
Means		.99	1.10	1.24	1.42		1.36	1.12	.99	.91	
Departures		+.07	+.07	+.06	+.07		+.01	−.06	−.05	−.01	

BLUE HILL, MASS.

Date	8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Nov. 1	6.1						0.94				5.1
Nov. 5	6.3						1.28	1.14	1.00	0.89	5.0
Nov. 6	3.8				1.31		1.37				3.5
Nov. 21	4.2		0.82	0.96	1.30		1.35	1.23	1.12	1.01	4.8
Nov. 22	3.5			1.06	1.29						3.3
Nov. 23	2.0	0.90	1.08	1.24	1.42		1.42	1.25	1.00	.89	2.1
Nov. 26	4.8			1.07							3.0
Nov. 27	2.0		1.00	1.09	1.34		1.34	1.22	1.07	.94	1.5
Nov. 28	1.6	.94	1.07	1.20							2.0
Nov. 30	1.8	.94	1.05	1.29	1.35		1.31	1.12	.88	.73	1.3
Means		.93	1.00	1.13	1.34		1.29	1.19	1.01	.89	

[1] Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct + diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca
	Gram-calories per square centimeter															
1936	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 29	257	154	256	141	180	315	40	216	308	333	306	288	209	111	85	375
Nov. 5	204	191	266	159	179	316	28	210	350	309	188	323	215	146	215	425
Nov. 12	219	317	261	160	182	249	12	171	297	266	291	293	210	103	96	472
Nov. 19	176	145	228	120	143	279	11	168	278	300	230	245	166	120	120	442
Nov. 26	124	137	176	115	159	244	20	153	254	311	150	254	182	92	95	460
	Departures from weekly normals															
Oct. 29	+11	−29	+18	−5	+6	−1	−1	−10		+14	+40	−18	−21		−27	−61
Nov. 5	−21	+27	+23	+33	+31	+9	−3	−2		−35	−83	−4	+19		+32	+89
Nov. 12	+23	+174	+54	+58	+55	+4	−14	+5		−76	+50	−8	+31		0	−14
Nov. 19	−13	+16	+22	+3	+17	+37	−8	+12		−28	+9	−27	+4		+27	+18
Nov. 26	−40	+13	−9	+29	+30	+23	+4	−3		+26	−63	−8	+33		+9	+5
							+4235									
	Accumulated departures on—															
	+5,474	+3,976	+8,351	+11,242	+7,854	+5,096		−2,660	......	−8,561		−889	−1,113		+1,449	+1,176

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during November 1936 and determinations of the atmospheric turbidity factor, β, and water-vapor content, m=depth in millimeters, if precipitated*

AMERICAN UNIVERSITY, WASHINGTON, D. C.

Date and hour angle	Solar altitude		Air mass	I_m	I_y	I_r	β_{I_y-r}	*$\frac{I_{u-c}}{1.94}$	*$\frac{I_{u-c}-I_m}{1.94}$	w	Air-mass type
								Percentage of solar constant			
1936											
Nov. 10	°	′	*m*	*gr. cal.*	*gr. cal.*	*gr. cal.*				*mm*	
3:06 a. m.	18	59	3.05	0.825	0.684	0.572	0.037	69.6	26.4	>50	N_P.
3:02 a. m.	19	36	2.96	.833	.686	.574	.039	68.0	25.4	>50	
Nov. 19											
1:13 a. m.	29	11	2.05	1.411	1.034	.832	.016	81.2	9.8	6.9	P_C.
1:18 a. m.	28	51	2.07	1.386	1.030	.832	.019	80.5	9.8	6.8	
Nov. 23											
0:40 a. m.	30	01	2.00	1.117	.865	.714	.086	66.3	9.3	5.4	N_P.
0:32 a. m.	30	16	1.98	1.126	.869	.710	.090	66.3	8.9	4.8	
Nov. 27											
2:40 a. m.	19	13	3.02	.724	.556	.482	.164	43.0	6.1	1.7	P_C.
2:33 a. m.	20	20	2.86	.709	.556	.482	.176	42.5	6.4	1.9	

* Corrected for mean solar distance.

Meteorological conditions during turbidity measurements

Nov. 10. Temperature 6° C.; wind, NW 14; polarization, 53.6 percent; visibility, 20 miles; blueness of sky, 5.
Nov. 19. Temperature −5° C.; wind, S 9; polarization, 57.6 percent; visibility, 30 miles; blueness of sky, 5.
Nov. 23. Temperature 2° C.; wind, NW 12; polarization, 52.8 percent; visibility 12 miles; blueness of sky, 4.
Nov. 27. Temperature −3° C.; wind, NW 14; polarization, 52.2 percent; visibility, 5 miles; blueness of sky, 4.

BLUE HILL OBSERVATORY OF HARVARD UNIVERSITY

Date and hour angle	Solar altitude		Air mass	I_m	I_y	I_r	*$\frac{I_y}{0.851+c}$	*$\frac{I_r}{0.840+c}$	β_{I_y-r}	*$\frac{I_{u-c}}{1.94}$	*$\frac{I_{u-c}-I_m}{1.94}$	w	Air-mass type
1936													
Nov. 1	°	′		*gr. cal.*	*gr. cal.*	*gr. cal.*						*mm*	
0:52 p. m.	32	32	1.86	0.990	0.678	0.525	0.785	0.617	0.092	67.6	17.3	12.0	N_P→Tm.
Nov. 5													
3:53 p. m.	11	49	4.79	.999	.667	.554	.768	.646	.089	55.0	7.8	3.9	P_C.
Nov. 6													
0:20 a. m.	32	44	1.85	1.307	.871	.705	1.001	.818	.070	71.8	5.6	4.0	P_C.
0:30 p. m.	32	44	1.85	1.366	.891	.707	1.025	.882	.045	76.1	6.9	4.9	
Nov. 21													
3:06 a. m.	14	31	4.08	.644	.469	.409	.567	.473	.142	40.2	7.8	3.8	N_{PP}.
0:08 a. m.	27	57	2.13	.957	.660	.528	.754	.610	.111	60.2	12.1	8.2	
3:10 p. m.	14	03	4.08	.556	.415	.348	.475	.403	.127	42.2	14.3	7.0	
Nov. 22													
2:31 a. m.	18	37	3.11	1.126	.730	.607	.835	.703	.077	58.5	7.0	3.8	P_P+P_C.
Nov. 23													
3:14 a. m.	13	40	4.16	1.055	.770	.677	.878	.781	.085	60.5	7.2	3.5	P_C.
2:12 a. m.	20	19	2.86	1.268	.878	.720	1.000	.830	.045	69.0	5.7	3.3	
0:55 p. m.	26	23	2.25	1.374	.927	.750	1.056	.864	.041	75.2	5.9	3.8	
3:14 p. m.	12	40	4.16	1.071	.786	.647	.908	.747	.025	67.8	14.0	6.8	
Nov. 26													
1:50 p. m.	21	56	2.66	1.100	.744	.632	.870	.741	.101	57.5	2.3	1.2	P_C.
Nov. 27													
3:14 a. m.	12	30	4.54	.981	.693	.605	.786	.695	.075	51.0	1.8	.7	P_C.
0:17 a. m.	26	36	2.22	1.331	.888	.730	1.007	.838	.071	67.9	1.1	.5	
1:39 p. m.	22	33	2.60	1.282	.862	.716	.979	.823	.068	66.6	2.3	1.6	
3:56 p. m.	......		......	.886	.553	.484	.628	.556	......	......	......	......	
Nov. 28													
3:14 a. m.	12	18	4.61	.970	.699	.592	.793	.688	.060	53.2	12.1	5.5	N_{PC}.
Nov. 30													
3:55 a. m.	......		......	.820	.665	.545	.755	.626	......	......	......	......	P_C.
0:21 a. m.	26	51	2.21	1.337	.913	.745	1.036	.856	.055	71.0	3.9	2.4	
3:42 p. m.	8	27	......	.521	.404	.360	.513	.413	......	......	......	......	

* Reduced to value at mean solar distance.

Atmospheric conditions during Smithsonian observations, November 1936

Date	Time from apparent noon	Temperature ° C.	Wind, Beaufort	Visibility	Sky blueness	Cloudiness and remarks
Nov. 1	1:56 p. m.	+15.9	SW 4	8	7	Few Ci, 1 Acu, light haze, instr. indoors.
5	3:29 p. m.	+7.5	NNW 5	9	7	Few Ci, 1 Cu.
9	0:17 p. m.	+5.6	NW 2	9	7	1 Cu, light haze.
9	2:55 p. m.	+7.2	W 1	9	8	Few Ci, light haze.
10	2:21 p. m.	+7.3	W 1	9	8	Few Cu, light haze, instr. indoors.
11	1:17 a. m.	−0.2	WNW 4	9	8	Zero clouds, light haze, instr. indoors.
12	2:54 a. m.	+3.1	SW 4	6	7	1 Ci, moderate haze.
13	2:02 a. m.	+5.3	N 4	5	6	Zero clouds, dense haze.
14	2:33 a. m.	+3.6	S 5	6	7	Few Ci, dense haze, instr. indoors.
15	0:21 a. m.	+9.1	W 4	8	7	Few Cu, light haze.
18	1:35 a. m.	−6.7	NNW 7	9	7	Few Acu, light haze, instr. indoors.
19	1:00 a. m.	−6.8	NW 6	9	7	Do.
21	3:00 a. m.	+6.7	SW 3	6	7	Few Ci, 2 Acu, moderate haze.
21	3:17 p. m.	+14.2	W 4	7	7	Few Ci, Few Acu, moderate haze.
23	2:08 a. m.	−4.2	WNW 5	9	7	Few Cu, light haze, instr. indoors.
23	0:35 p. m.	−1.9	NW 5	9	8	Few Cu, light haze, instr. indoors.
26	1:50 p. m.	−0.8	WNW 5	8	7	Few Acu, few Cu, light haze, instr. indoors.
27	3:10 a. m.	−7.5	WSW 3	7	7	Few Ci, few cu, light haze, instr. indoors.
27	1:43 p. m.	−4.6	W 4	8	7	Do.
28	3:09 a. m.	−8.8	S 3	7	7	Zero clouds, moderate haze.
30	3:51 a. m.	−7.7	W 4	8	7	Few Stcu, Frcu, Cu, light haze.

POSITIONS AND AREAS OF SUN SPOTS

Note.—The report for December 1936, not having been received in time, will be included in the January 1937 issue of the REVIEW.—*Ed.*

PROVISIONAL SUN-SPOT RELATIVE NUMBERS, NOVEMBER 1936

[Dependent alone on observations at Zurich and its station at Arosa]

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen, Sternwarte, Zurich, Switzerland]

November 1936	Relative numbers	November 1936	Relative numbers	November 1936	Relative numbers
1	*d* 118	11	*Eac* 148	21	28
2	*a* --	12	*aa* 133	22	*b* 39
3	*Eac* 149	13	*a* --	23	*d* 46
4	*ad* 140	14	*ab* --	24	43
5	159	15	119	25	*Ecd* 70
6	*Eacd* 151	16	95	26	96
7	*ad* 127	17	*Ec* 92	27	*d* 141
8	*Ecd* 140	18	61	28	*Ec* 212
9	127	19	60	29	*ab* 192
10	150	20	----	30	----

Mean, 25 days=113.4.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group or spot through the central meridian.
c=New formation of a group developing in a middle-sized or large center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central circle zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE in charge]

By L. P. HARRISON

Mean free-air temperatures and relative humidities for November, as determined from airplane weather observations, are given in table 1. The "departures from normal" given in the table are based on "normals" derived from the number of observations indicated in the note at the foot of the table, where the number of years over which the observations were taken are given by the figures in parentheses. In general, the numbers of observations available for computing "normals" for the higher levels are less than those available for the lowest levels (represented by the data given in the footnote). To compensate for this discrepancy, the "normals" are obtained by applying the mean differences between the successive standard levels to the data for the lower levels, where the "normal" for the surface based on the indicated number of observations serves as the reference basis. The "normals" in each case include the data for the current month. It will be noted that many of the "normals" are based on only 3 years of observations. "Departures from normal" in such cases must be regarded as having little weight in comparison with departures from "normals" based on much more extended periods of record (35 or more years, say, which are not uncommon in climatology).

The mean temperatures for the month at the surface (see chart I) were generally below normal in the eastern half of the country, and in most of Texas and southern New Mexico, as well as in a large part of the extreme northwest portion of the country with the exception of northwestern Washington, which had above-normal temperatures. The largest negative departures from normal at the surface were to be found in the Great Lakes region and southward for several hundred miles, with an average of about −2° C., and also in the northern half of the extreme northwest portion of the country (excepting northwest Washington) with an average of nearly −3° C. The remaining portion of the country and southwestern Canada largely had above-normal temperatures at the surface, with maximum positive departures to be found in the southern California coast region, and notably in southwestern Canada where the average departure from normal appeared to be slightly over +4° C.

The mean temperatures for the month in the free air (see table 1) appeared to show that the significant negative departures from normal observed at the surface near and somewhat to the south of the Great Lakes region were not merely superficial but were also predominantly in evidence at all elevations up to at least 5 km in the northeast sector of the country, with perhaps the exception of the levels from 3 to 5 km near the coastal area adjacent to New York. (See Mitchel Field.) If we may regard the departures from normal given in table 1 as representative, the data for Selfridge Field (Mount Clemens, near Detroit), Mich., Wright Field (Dayton), Ohio, and Omaha, Nebr., indicate that departures from about −2° to −4° C., prevailed in the area under consideration.

The mean temperatures for the month in the free air also gave evidence that the extreme northwest part of the country at all levels up to 5 km, except the lowest stratum near the ground, was dominated by positive departures from "normal temperatures" ranging from 0° to a maximum of +4° C. This condition apparently was associated in some manner with the similar above-normal temperatures observed at the surface in southwestern Canada and northwestern Washington.

Mean free-air relative humidities for the month were slightly above normal in the extreme southwestern portion of the country at practically all levels up to 5 km, and also in the south-central portion at moderate and higher elevations (2.5 to 5 km). (Note departures: +5 percent to 8 percent at San Diego from 1.5 to 5 km; +7 to 11 per-

cent at Kelly Field (San Antonio) from 3 to 5 km). Elsewhere and at other levels the departures from normal relative humidities were largely of negative sign. The regions of most notable *below-normal humidities* could be more or less closely identified, respectively, with the Great Lakes-south central regime of *below-normal temperatures* referred to above, especially at moderate elevations (note departures from −13 percent to −17 percent at Wright Field (Dayton), Ohio, from 2 to 4 km, and the Oklahoma City departures), and perhaps, anomalously, also with the extreme northwestern regime of *above-normal temperatures* referred to in the preceding paragraph (note departures: −12 percent to −17 percent at Spokane from 1.5 to 5 km). The extreme northeast coastal area had significant negative departures from normal as evidenced by the data for Boston (ranging from −7 percent to −12 percent from 1.5 to 5 km) and for Mitchel Field (ranging between −5 percent and −12 percent from 1.5 to 5 km).

The free-air resultant winds based on pilot balloon observations made near 5 a. m. (seventy-fifth meridian time) during the month of November are given in table 2. Generally speaking, the resultant winds were largely normal in direction but slightly above-normal in velocity at practically all levels up to about 2 km above sea level in the region over the country east of a line extending from eastern Mississippi in the southeast to western Montana in the northwest. The largest departures in resultant velocities from normal were to be found concentrated in the northeast sector of the country, as exemplified by the data for Newark, N. J., with departures of +4.1 m. p. s. at 2.5 km, and Washington, D. C., with departures of +3.3 m. p. s. at 1.5 and 2 km. The most marked departures in direction of the resultant wind from normal in the region under consideration were to be found at Sault Ste. Marie, Mich., where orientations of nearly 40° clockwise (i. e., more from the north) occurred in the monthly resultant direction as compared with the normal.

Excepting the south-central part of the country near the surface, and the California coastal stations at practically all levels up to at least 2 km, the resultant wind velocities in the region of the country to the west of the line extending from eastern Mississippi to western Montana were generally below normal by slight amounts up to about 2 km above sea level, and the resultant directions were largely near normal. Most of the significant exceptions may be noted from the following comparisons (station; elevation, November 1936; resultant direction and velocity in m. p. s.; and in parentheses, normal resultant direction and velocity in m. p. s.): Houston, Tex., 500 m, 66°, 2.7 (163°, 2.6); 1,000 m, 326°, 0.7 (209°, 2.2). Oklahoma City, Okla., 500 m, 267°, 1.9 (205°, 2.7); 1,000 m, 311°, 4.4 (252°, 5.4); 1,500 m, 310°, 5.1 (273°, 5.7). Albuquerque, N. Mex., 2,000 m, 334°, 0.9 (296°, 1.7). San Diego, Calif., 1,500 m, 69°, 3.7 (359°, 1.5); 2,000 m, 64°, 4.2 (355°, 1.8). Oakland, Calif., 1,500 m, 72°, 2.7 (349°, 2.4); 2,000 m, 114°, 1.4 (344°, 2.6).

Above 2 km to perhaps 4 or 5 km, the resultant winds in the northern third of the country during November were in general slightly above normal in velocity, and nearly normal or oriented slightly clockwise with respect to normal in direction. At these elevations in the southern two-thirds of the country, with the exception of the extreme southeast and the California coastal areas, the resultant velocities for the month were in general slightly below normal and the resultant directions were as just indicated for the northern third of the country. In the extreme southeast, Pensacola, Fla., had normal directions but significant positive departures (about 4 m. p. s.) of velocity of the resultant winds at 3 and 4 km. Key West, Fla., had only slight departures of resultant velocity from the normal at moderate elevations (2–3 km), but had considerable departures from normal in direction (40° to 56° counterclockwise). The most radically marked departures from normal direction at the elevations from about 2 to 4 km prevailed at Oakland, Calif., as shown by the following comparisons (see preceding paragraph regarding arrangement): 2500 m, 164°, 4.8 (341°, 3.2); 3000 m, 187°, 4.0 (342°, 3.5); 4000 m, 195°, 2.4 (351°, 1.9). Thus the normal northerly resultant winds at these elevations were replaced by southerly resultant winds. At 5 km, the normal westerly resultant winds at San Diego were replaced by an easterly resultant, while other stations in the western part of the country showed significant clockwise departures of resultant direction from normal which ranged from about 45° to 60° in magnitude. Albuquerque, N. Mex., showed a remarkable negative departure in velocity at 5 km, as indicated by the following comparison (see above): 335°, 1.3 (287°, 7.4).

The observational data discussed above have added significance when regarded in terms of the sequence of meteorological events which occurred during the month of November. During the month in question, the weather of the country was largely dominated by the passage of one anticyclone after another, either of P_c or P_P origin or both. Many of the high-pressure systems moved southward from Canada into the Northwestern States and then curved to acquire an eastward motion across the country. (The above-normal resultant velocities in the northern part of the country noted above may be recalled.) Many of the Pacific HIGHS which reached the north-central part of the country seemed to be reinforced by cold P_c air moving from the Mackenzie River-Hudson Bay area. Accordingly, a frequent type of atmospheric cross section in the northeastern part of the country was P_c or N_{PC} air masses overlain by P_P or N_{PP} air masses. These air masses of cold and relatively dry characteristics gave rise to the subnormal temperatures already referred to above. The polar air masses, especially P_P and N_{PP}, had associated with them unusually dry conditions at moderate elevations (ca. 2–3 km), leading to the conclusion that considerable subsidence had occurred therein to produce the dryness. The subsidence in question may help to explain the apparently above-normal temperatures observed at moderate and higher elevations over the extreme northwest part of the country. The relatively moist T_M air masses occurred generally only in the southeastern part of the country, owing to the southward displacement of the polar air masses. Thus, with the ordinary supply of moisture lacking, a deficiency of precipitation was observed over most of the country. Nearly normal or slightly above-normal precipitation occurred in several small regions, notably the area immediately near and to the south of the Great Lakes, South Dakota, and some south Atlantic States as well as other isolated places (see inset chart V). Precipitation was very deficient along the Pacific Coast, the weather of which was dominated by the successive HIGHS that reached the western Plateau region from Canada and also by the Pacific HIGHS which moved eastward across the coast. The air trajectories were accordingly such that the dry P_P, N_{PP} (and also mixtures of N_{PC}) air masses reached the Pacific Coast region, instead of the more moist air masses from the middle Pacific Ocean at moderate and low elevations which usually are prevalent.

TABLE 1.—*Mean free-air temperatures and relative humidities obtained by airplanes during November 1936*

TEMPERATURE (°C.)

Station	Surface Mean	Surface Departure from normal	500 Mean	500 Departure from normal	1,000 Mean	1,000 Departure from normal	1,500 Mean	1,500 Departure from normal	2,000 Mean	2,000 Departure from normal	2,500 Mean	2,500 Departure from normal	3,000 Mean	3,000 Departure from normal	4,000 Mean	4,000 Departure from normal	5,000 Mean	5,000 Departure ftom normal	Number of observations
	Altitude (meters) m. s. l.																		
Barksdale Field (Shreveport), La.[1] (52 m)	7.1		11.0		9.9		8.5		7.0		5.1		3.2		−2.0		−7.8		27
Billings, Mont.[3] (1089 m)	0.4	+0.1					4.7	+0.6	3.8	+1.2	0.9	+1.2	−2.1	+1.3	−6.4	+2.8	−13.0	+2.8	29
Boston, Mass.[1] (5 m)	1.0	−2.3	−0.2	−2.1	−1.9	−2.1	−3.1	−2.2	−4.8	−2.5	−6.6	−2.5	−8.5	−2.3	−13.3	−2.2	−18.7	−1.4	20
Cheyenne, Wyo.[3] (1873 m)	−1.2	+0.1							0.5	−0.3	1.6	+0.1	−1.0	+0.3	−6.6	+0.8	−13.4	+0.7	30
El Paso, Tex.[3] (1,194 m)	6.0						8.8		7.8		6.2		4.3		−1.0		−7.7		30
Fargo, N. Dak.[3] (274 m)	−5.7	−0.3	−3.2	+0.1	−2.9	−0.3	−2.9	−0.7	−3.8	−0.6	−5.6	−0.4	−7.6	−0.1	−12.2	+0.7	−18.3	+0.9	28
Kelly Field (San Antonio), Tex.[1] (206 m)	9.2	−1.8	13.0	−1.2	11.6	−2.0	9.9	−1.9	8.8	−1.2	7.3	−0.7	5.2	−0.5	−0.5	−0.1	−7.9	−0.4	25
Lakehurst, N. J.[2] (39 m)	4.0	−2.1	4.5	−1.8	3.0	−1.6	1.3	−2.0	−0.1	−2.0	−1.2	−1.4	−3.2	−1.6	−8.6	−1.9			25
Maxwell Field (Montgomery), Ala.[1] (52 m)	9.1	−0.9	11.2	−1.4	9.3	−1.9	8.3	−1.7	7.2	−1.2	5.7	−0.6	3.5	−0.6	−1.7	−0.1	−7.9	+0.3	24
Miami, Fla.[3] (4 m)	19.1		20.3		16.3		13.2		11.8		11.4		8.9		2.9		−3.2		30
Mitchel Field (Hempstead, L. I.), N. Y.[1] (29 m)	3.6	−2.2	3.7	−2.0	1.8	−2.1	0.6	−1.5	−0.2	−0.9	−1.2	−0.2	−2.6	+0.4	−7.2	+1.9	−12.4	+3.1	21
Murfreesboro, Tenn.[3] (174 m)	4.2	−2.2	5.7	−2.0	5.1	−1.8	4.4	−1.8	3.2	−1.7	1.3	−1.3	−0.6	−1.1	−5.7	−0.7	−11.4	−0.2	29
Norfolk, Va.[3] (10 m)	7.3	−1.6	7.4	−1.6	4.8	−2.1	3.6	−1.4	2.9	−0.3	1.1	−0.5	−1.3	−1.1	−7.0	−1.4	−13.0	−1.0	21
Oakland, Calif.[3] (2 m)	9.2		15.4		15.0		13.6		11.1		8.5		5.5		−0.8		−7.9		30
Oklahoma City, Okla.[3] (391 m)	4.9	−1.6	7.4	−0.5	8.8	−0.4	8.0	−0.5	6.2	−0.3	4.0	−0.2	2.0	+0.2	−2.9	+0.9	−9.2	+1.0	29
Omaha, Nebr.[3] (300 m)	−0.4	−1.6	1.8	−0.7	2.3	−1.5	1.9	−1.5	0.2	−1.9	−1.6	−1.8	−4.0	−1.8	−9.6	−1.5	−16.6	−2.0	30
Pearl Harbor, Territory of Hawaii[2] (6 m)																			
Pensacola, Fla.[3] (13 m)	10.9	−1.8	13.0	−0.4	11.8	−0.4	10.5	−0.2	9.7	+0.5	7.9	+0.8	5.4	+0.6	0.4	+1.0	−5.4	+1.3	27
Salt Lake City, Utah[2] (1288 m)	−2.0						2.7		3.1		2.0		−0.4		−6.1		−12.5		30
San Diego, Calif.[3] (10 m)	12.0	−2.5	17.6	+1.5	15.9	+0.4	13.1	−0.2	10.2	−0.6	7.3	−1.0	4.7	−1.0	−1.8	−1.2	−9.0	−1.4	30
Sault Ste. Marie, Mich.[3] (221 m)	−4.3		−4.9		−7.2		−7.8		−8.6		−10.1		−12.3		−17.1		−22.7		29
Scott Field (Belleville), Ill.[1] (135 m)	−0.5	−3.0	2.5	−2.4	3.0	−1.3	3.1	−0.7	2.4	−0.1	0.6	0.0	−1.9	−0.1	−7.3	−0.3	−13.4	−0.2	25
Seattle, Wash.[3] (10 m)	7.4		9.0		8.1		5.8		4.2		1.7		−0.2		−6.0				3
Selfridge Field (Mount Clemens), Mich.[1] (177 m)	0.2	−2.7	0.3	−3.6	−1.7	−4.1	−2.7	−3.8	−3.9	−3.7	−5.7	−3.5	−7.8	−3.5	−12.8	−3.4	−18.8	−3.5	29
Spokane, Wash.[3] (596 m)	−2.0	−1.0			2.1	+1.2	3.3	+2.5	3.3	+3.6	1.7	+4.2	−0.9	+4.2	−6.3	+4.2	−12.8	+4.1	29
Washington, D. C.[3] (13 m)	4.5	−1.2	5.1	−0.6	2.4	−1.8	0.5	−2.1	−0.3	−1.4	−1.5	−1.2	−3.0	−0.9	−8.4	−1.2	−14.6	−1.5	28
Wright Field (Dayton), Ohio[1] (244 m)	−1.0	−3.3	−0.6	−4.2	−1.5	−4.6	−2.2	−3.9	−2.9	−3.4	−3.9	−2.7	−6.3	−2.6	−11.1	−2.0	−17.2	−2.2	22

RELATIVE HUMIDITY (PERCENT)

Station	Surface Mean	Surface Departure from normal	500 Mean	500 Departure from normal	1,000 Mean	1,000 Departure from normal	1,500 Mean	1,500 Departure from normal	2,000 Mean	2,000 Departure from normal	2,500 Mean	2,500 Departure from normal	3,000 Mean	3,000 Departure from normal	4,000 Mean	4,000 Departure from normal	5,000 Mean	5,000 Departure from normal	Number of observations
Barksdale Field (Shreveport), La.	84		63		58		54		51		51		51		47		47		
Billings, Mont.	65	0					52	−1	48	−2	49	−3	50	−4	47	−7	46	−7	
Boston, Mass.	69	−4	65	−5	63	−6	53	−10	47	−12	45	−10	44	−9	43	−7	37	−12	
Cheyenne, Wyo.	60	−2							57	−3	50	−3	48	−4	43	−7	43	−6	
Colo Solo, C. Z.																			
El Paso, Tex.	62						51		49		48		44		43		40		
Fargo, N. Dak.	79	−4	71	−7	66	−5	55	−6	50	−4	46	−5	47	−3	44	−4	47	−1	
Kelly Field (San Antonio), Tex.	84	−2	57	−11	57	−6	59	+1	55	+2	51	+3	47	+7	43	+7	42	+11	
Lakehurst, N. J.	81	−2	74	−4	70	−6	68	−3	63	−1	54	−4	51	0	51	+4			
Maxwell Field (Montgomery), Ala.	70	−9	54	−8	53	−6	49	−2	39	−6	32	−7	34	−2	36	+4	34	+3	
Miami, Fla.	87		73		77		72		62		43		41		39		35		
Mitchel Field (Hempstead, L. I.), N. Y.	82	−2	76	−1	71	−3	64	−6	56	−7	47	−8	37	−12	40	−5	30	−10	
Murfreesboro, Tenn.	84	+2	71	−1	66	−2	52	−7	41	−7	37	−7	36	−3	36	−1	35	−2	
Norfolk, Va.	74	−1	61	−4	58	−3	55	−3	47	−7	42	−5	41	0	42	+5	36	+3	
Oakland, Calif.	81		49		38		31		28		24		22		20		21		
Oklahoma City, Okla.	69	−8	62	−10	51	−10	45	−10	43	−9	43	−7	39	−7	36	−5	34	−5	
Omaha, Nebr.	78	−2	70	−4	61	−3	52	−4	48	−2	44	−2	44	−1	42	−2	41	−2	
Pearl Harbor, Territory of Hawaii																			
Pensacola, Fla.	80	−1	65	−6	59	−5	55	−4	44	−7	37	−8	35	−6	28	−6	25	−5	
Salt Lake City, Utah	79						60		50		44		41		38		36		
San Diego, Calif.	73	+3	56	0	45	+2	41	+5	38	+7	36	+8	34	+8	33	+8	32	+7	
Sault Ste. Marie, Mich.	75		78		80		70		64		61		58		56		58		
Scott Field (Belleville), Ill.	81	0	66	0	58	−3	49	−5	43	−6	39	−6	39	−5	38	−5	38	−3	
Seattle, Wash.	91		77		73		74		65		61		55		56				
Selfridge Field (Mount Clemens), Mich.	77	−4	75	+1	74	+2	63	−4	55	−3	51	−2	51	0	53	+5	53	+9	
Spokane, Wash.	85	0			69	−6	54	−12	48	−14	45	−16	43	−16	37	−17	38	−14	
Washington, D. C.	71	−3	60	−5	62	+1	59	+1	49	−5	46	−4	38	−6	35	−6	36	−1	
Wright Field (Dayton), Ohio	85	+3	77	+3	65	−1	51	−8	38	−13	31	−17	28	−17	33	−13	39	−7	

[1] Army. [2] Weather Bureau. [3] Navy.

Observations taken about 4 a. m., 75th meridian time, except along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month (years of record are given in parentheses following the number of observations): Billings, 87 (3); Boston, 102 (5); Cheyenne, 89 (3); Fargo, 86 (3); Kelly Field, 76 (3); Lakehurst, 78 (3); Maxwell Field, 78 (3); Mitchel Field, 70 (3); Murfreesboro, 87 (3); Norfolk, 135 (8); Oklahoma City, 86 (3); Omaha, 174 (6); Pensacola, 174 (9); San Diego, 187 (8); Scott Field, 69 (3); Selfridge Field, 77 (3); Spokane, 85 (3); Washington, 202 (12); Wright Field, 68 (3). (Departures from normal for Seattle are omitted from this summary because of the paucity of observations.)

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during November 1936*

[Wind from N=360°, E=90°, etc.]

Altitude (m) m. s. l.	Albuquerque, N. Mex. (1,554 m)		Atlanta, Ga. (309 m)		Billings, Mont. (1,088 m)		Boston, Mass. (15 m)		Cheyenne, Wyo. (1,873 m)		Chicago, Ill. (192 m)		Cincinnati, Ohio (153 m)		Detroit, Mich. (204 m)		Fargo, N. Dak. (274 m)		Houston, Tex. (21 m)		Key West, Fla. (11 m)		Medford, Oreg. (410 m)		Murfreesboro, Tenn. (180 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	12	1.3	333	2.1	241	5.5	273	2.9	291	3.4	270	2.2	261	1.0	266	3.0	317	2.0	19	2.3	35	3.5	138	0.4	213	1.0
500			322	4.6			283	9.4			274	6.2	263	4.0	276	6.7	318	6.1	66	2.7	55	7.2	23	0.2	248	3.4
1,000			306	6.3			281	10.2			277	8.7	267	8.4	286	8.4	325	8.5	326	0.7	71	5.4	128	2.0	259	6.4
1,500			290	7.4	273.	9.7	285	9.2			271	11.1	275	11.6	282	10.5	313	9.1	297	1.8	80	2.6	141	2.5	267	6.9
2,000	334	0.9	292	9.4	299	10.2	282	11.0	295	7.0	278	12.5	280	10.9	287	8.3	313	11.8	292	3.5	18	0.7	187	1.3	290	8.2
2,500	292	1.7	296	8.7	297	11.2			311	9.6	284	13.4	299	11.7	295	11.3	321	11.5	286	4.3	356	1.2	251	0.7	292	10.1
3,000	284	2.4	280	7.5	302	11.2			318	8.6	291	11.6	293	11.0	294	12.3			285	5.1	308	1.6	290	1.3	296	7.8
4,000	269	4.2	273	10.4	315	10.5			314	8.4									279	5.8	291	4.8	213	3.4		
5,000	335	1.3			335	11.2			360	5.7									278	4.7			340	3.2		

Altitude (m) m. s. l.	Newark, N. J. (14 m)		Oakland, Calif. (8 m)		Oklahoma City, Okla. (402 m)		Omaha, Nebr. (306 m)		Pearl Harbor, Territory of Hawaii [1] (68 m)		Pensacola, Fla.[1] (24 m)		St. Louis, Mo. (170 m)		Salt Lake City, Utah (1,294 m)		San Diego, Calif. (15 m)		Sault Ste. Marie, Mich. (198 m)		Seattle, Wash. (14 m)		Spokane, Wash. (603 m)		Washington, D. C. (10 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	287	2.4	92	1.1	278	1.0	307	1.6			13	3.5	268	2.3	161	1.5	67	0.6	286	0.8	126	0.5	77	1.4	295	1.1
500	282	7.3	48	2.4	267	1.9	296	3.4			24	2.9	281	5.5			51	1.7	278	2.0	274	.7			283	7.2
1,000	285	10.0	50	2.8	311	4.4	308	8.0			310	2.7	293	8.9			53	2.0	316	5.4	239	2.2	131	1.5	282	9.9
1,500	276	11.0	72	2.7	310	5.1	308	8.0			306	4.0	300	10.2	189	0.9	69	3.7	312	7.7	219	3.2	231	2.4	292	11.9
2,000	275	12.1	114	1.4	295	4.0	308	9.5			315	6.3	292	10.1	215	1.0	64	4.2	331	7.9	238	4.0	270	3.9	286	13.3
2,500	282	15.4	164	4.8	300	4.8	297	9.8			299	6.9	293	9.4	284	1.5	57	4.5	314	10.4	257	4.7	272	6.1	291	14.5
3,000	278	15.0	187	4.0	303	5.6	293	9.4			293	10.6	300	7.9	322	3.8	42	4.7	332	12.1	274	5.5	280	7.7		
4,000			195	2.4	296	5.6	281	10.5			273	9.2	304	4.4	307	4.5	32	2.5					294	8.4		
5,000															1	7.7	93	1.5								

[1] Navy stations.

RIVERS AND FLOODS

[River and Flood Division, W. J. MOXOM, temporarily in charge]

By BENNETT SWENSON

During the month, which was otherwise quite dry, a period of excessive rainfall occurred from the 1st to the 4th in the lower Missouri Basin, the middle Mississippi Basin, the Ohio Basin, and the Lake region. The heaviest rain fell in Indiana and in parts of Illinois and Ohio.

As a result of this rainfall, stages that were quite low at the beginning of the month rose considerably to stages slightly above flood stage, principally in the Wabash River Basin and in tributaries of the middle and lower Mississippi River.

The official in charge of the Weather Bureau office at Indianapolis, Ind., reports as follows on the floods in the Wabash River Basin:

All river stages were very low at the beginning of the month, but a period of excessive rainfall, beginning at most places during the day of November 1 and continuing until the morning of the 3rd caused rapid rises in parts of the upper stretches, and rather slower rises in the lower channels. By far the greater proportion of the excessive rainfall occurred for the most part during the 24-hour period ending at 7 a. m. C. S. T. on November 3. Reports on the morning of November 3 showed excessive rainfall averaging from 3 to 4 inches over the various subdivisions of the basin.

In the recollection of the writer, this flood period was the only one of substantial changes from low to flood or comparatively high stages since his taking charge of the Indianapolis River district in 1914, that occurred throughout the basin, and ran its full course, on a single period of excessive rainfall.

The following account of an unusual rise in the lower Missouri River at Hermann, Mo., where the river rose from 2.1 feet at 7 a. m. of the 2d to 14.1 feet at 7 a. m. of the 3d, was received from the Weather Bureau office, St. Louis, Mo.:

The remarkable rise of 12 feet in 24 hours at Hermann, Mo., November 2–3, equals the previous record for greatest 24-hour rise. It occurred only once before, viz, February 19–20, 1882.

The 24-hour rise of 8.1 feet at St. Louis, Mo., November 3–4, was also quite unusual; but it has been exceeded several times. The greatest 24-hour rise recorded at St. Louis was 13.2 feet on January 3–4, 1897.

Doubtless, greater 24-hour changes would be shown if the 24-hour periods could be taken from any time of day and not confined to the period 7 a. m. to 7 a. m.

Moderate rises occurred in the lower Ohio and middle Mississippi Rivers as a result of the excessive rainfall. The mean stage at Cairo, Ill., on the Ohio River, was 17.4 feet as compared to a 60-year normal of 13.4 feet for the month.

The Santee River in South Carolina was near, at, or slightly above flood stage most of the month. There were heavy rains in South Carolina on the 13th, but most of the excess water was a result of floods during October. As there is a gradual run-off in the low, swamp area of that section.

The amount of loss or damage from the floods of the month was small because the farm crops had been, in the main, harvested.

Stages in the Columbia River Basin were exceptionally low during the month due to the dry summer and fall

season in that area. The Weather Bureau office, Portland, Oreg., reports as follows:

The month was the driest November of record at Portland, Oreg., and from reports this condition was general over the entire Northwest. It is thought that the period July to November 1929 was slightly drier than for the same period this year.

The stages of the Columbia River and its tributaries were very low at the end of November. Except in one or two instances, the monthly averages were slightly above those in 1929 as shown in following table:

Station	Number of years record	November average	November 1929 average	November 1936 average
Albany, Oreg	42	4.1	0.5	0.4
Bonners Ferry, Idaho	31	1.6	−.9	−.8
Eugene, Oreg	35	2.7	−1.8	−2.3
Eula, Oreg	13	2.8	1.6	1.1
Jefferson, Oreg	30	3.4	.6	−.3
Lewiston, Idaho	32	2.3	1.9	[1] 1.0
Kelso, Wash	13	5.4	2.7	2.8
Mehama, Oreg	14	3.3	1.4	1.5
Oregon City, Oreg	25	4.7	1.3	2.6
Salem, Oreg	36	3.0	[2] −2.7	[2] −4.1
The Dalles, Oreg	39	3.4	----------	−1.5
Umatilla, Oreg	39	2.9	----------	.6
Vancouver, Wash	32	2.9	.1	−.1
Waterloo, Oreg	14	4.0	2.0	2.1
Weiser, Idaho	29	4.1	[3] 4.4	[3] 3.4
Portland, Oreg	58	3.9	.7	.8

[1] 0.9 foot in 1931 and 1934.
[2] Low stages recent years due to dredging.
[3] 2.9 feet in 1931 and 1934.

Table of flood stages during November 1936

[All dates in November unless otherwise specified]

River and station	Flood stage	Above flood stages—dates From—	Above flood stages—dates To—	Crest Stage	Crest Date
ST. LAWRENCE DRAINAGE					
Lake Erie					
St. Joseph:	*Feet*			*Feet*	
Fort Wayne, Ind	12	4	4	12.0	4
Montpelier, Ohio	10	5	5	10.0	5
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Santee:					
Rimini, S. C	12	Oct. 2	2	17.6	Oct. 22
		4	8	13.1	7
		12	16	13.3	15
		18	22	12.9	22
		25	([1])	12.8	27
Ferguson, S. C	12	Oct. 5	9	14.0	Oct. 23, 24
		13	17	12.5	16
		19	23	12.5	22
		26	([1])	12.4	29
MISSISSIPPI SYSTEM					
Missouri Basin					
Osage: Osceola, Mo	20	4	4	20.6	4
Ohio Basin					
Kiskiminetas: Saltsburg, Pa	8	5	5	10.5	5
West Fork of White:					
Anderson, Ind	8	3	3	8.2	3
Elliston, Ind	18	4	8	22.2	7
Edwardsport, Ind	12	4	10	17.6	8, 9
East Fork of White: Seymour, Ind	14	4	7	16.4	6
White:					
Petersburg, Ind	16	8	11	17.3	11
Hazleton, Ind	16	8	13	17.6	11
Wabash:					
La Fayette, Ind	11	3	8	19.7	4
Covington, Ind	16	3	9	23.2	6
Terre Haute, Ind	14	4	12	18.2	9
Vincennes, Ind	14	----------	----------	13.7	13
White Basin					
Black: Black Rock, Ark	14	3	3	14.2	3
Arkansas Basin					
Petit Jean: Danville, Ark	20	4	5	20.3	5
Lower Mississippi Basin					
St. Francis:					
Fisk, Mo	20	4	8	23.3	6
St. Francis, Ark	18	10	13	19.1	12

[1] Continued into December.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, I. R. TANNEHILL in charge]

NORTH ATLANTIC OCEAN, NOVEMBER 1936

By H. C. HUNTER

Atmospheric pressure.—The average pressure for November shows substantially the same contrasts with the normal that were displayed during the preceding month. Averages lower than normal were indicated for north-central and northeastern portions, while over and for a considerable distance around the Azores, pressure exceeded the normal, the average at Horta having a positive departure of practically a fifth of an inch.

The extremes of pressure found in vessel reports are 30.64 and 28.34 inches. The higher of these readings was noted on the American steamship *Dryden*, at 11 a. m., the 30th, at latitude 45°48′ N., longitude 18° W. The lower mark was recorded on the Danish steamship *Kentucky*, at 10 a. m., the 12th, at 53°30′ N., 39°10′ W.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, November 1936*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.44	−0.12	30.04	11, 30	28.34	17
Reykjavik, Iceland	29.55	−.07	30.27	24	28.68	19
Lerwick, Shetland Islands	29.69	−.01	30.48	22	28.79	8
Valencia, Ireland	29.91	+.02	30.51	20, 21	28.55	7
Lisbon, Portugal	30.10	+.06	30.42	14	29.71	25
Madeira	30.08	+.07	30.33	11,14,15	29.77	19, 25, 26
Horta, Azores	30.32	+.19	30.48	2	29.92	27
Belle Isle, Newfoundland	29.81	+.04	30.64	3	28.76	17
Halifax, Nova Scotia	29.91	−.04	30.56	6	29.20	16
Nantucket	30.01	−.04	30.61	6	29.33	15
Hatteras	30.11	.00	30.49	11	29.58	15
Bermuda	30.11	+.03	30.38	2	29.68	16
Turks Island	29.98	−.01	30.06	28	29.84	4
Key West	30.04	+.02	30.32	28	29.83	5
New Orleans	30.19	+.09	30.48	27	29.80	30

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—The month was marked by numerous strong gales over North Atlantic waters, particularly to the eastward of the thirty-fifth meridian. The stormiest period was the 5th to 12th. At this time unusually strong gradients were the rule between high pressure in the region around the Azores and Madeira, and low pressure in the northeastern area embracing the British Isles, Iceland, and waters between.

The first few days of the month saw considerable storminess. About 300 miles east-northeast of Newfoundland the Swedish motorship *Blankaholm* encountered force-12 wind on the 1st, while the Swedish steamship *Braheholm* met a wind of like strength on the 5th when approximately 300 miles southeast of the southern tip of Greenland. The latter occurrence was connected with a LOW which was centered just west of Iceland on the 2d, and moved irregularly but mainly southeastward, till it reached northern Ireland and western Scotland, where it was almost stationary from the 6th to the 9th, thereafter moving away toward the northeast. During this long period its intensity varied considerably, but at times was very marked. As a result of this storm the German motorship *Isis* sank during the night of the 8–9th, when near latitude 50° N., longitude 11° W. Only one cabin boy was saved of the crew of about 35 on board.

Quickly following this storm, a LOW which had displayed only moderate strength to westward of mid-Atlantic, intensified decidedly during the 10th and 11th and greatly affected waters within moderate distances west of Ireland and around the British Isles until the center reached the North Sea on the 13th. The British motorship *Sylvafield* on the 12th, in the English Channel, noted wind of force 12 in connection with this storm.

About the same time a rapidly developing storm affected the east coast of the United States, the center moving from the eastern Gulf of Mexico on the morning of the 12th to the vicinity of Cape Race on the 14th. During the night of the 12–13th, the American steamship *Siboney*, when near Hatteras, noted force-12 wind. The conditions on the morning of the 13th are displayed on chart IX.

On the morning of the 14th a LOW of large area was central near the southern end of Hudson Bay; it advanced first toward the southeast, then toward the northeast, and on the morning of the 17th was centered near Cape Farewell, with pressure below 28.40 inches. A long southward extension of the LOW had developed as it approached the eastern coast of the continent, and this, too, had become quite intense. A few steamers were crippled in their encounter with the high seas at this time, the British steamship *Sheaf Spear* being near Bermuda when it suffered injury, and presently making harbor there. Considerably farther to the northward, on the British motorship *Tweedbank*, the captain was swept against a winch, suffering fatal injury, and one sailor was washed overboard and lost.

By the 22d a later storm from the northern interior of the North American continent had come near the eastern coast, and on the morning of the 23d was centered near the Gulf of St. Lawrence, with marked energy, having united with a storm which traveled north-northeastward near the coast line. (See chart X.) This storm also took a northeastward course toward southern Greenland, and soon ceased to have important effects along the chief steamship routes.

In general, the eastern and central portions of the North Atlantic had but little stormy weather during the final fortnight of November, and, indeed, the last 6 days were almost without reports of gales anywhere over the North Atlantic Ocean.

Fog.—During November 1936 fog was of comparatively infrequent occurrence over the North Atlantic, as is expected during the late autumn. In nearly all the 5°-squares reports indicate fewer fogs than there had been in October just preceding.

To eastward of the thirtieth meridian about the only dates when fog was met were from the 16th to 19th, and no single area had fog then on more than 2 days. The square, including part of southeastern Newfoundland, namely, 45° to 50° N., 50° to 55° W., had reports of fog on 8 days, leading all other like areas in frequency. Here and elsewhere over and near the Grand Banks the final 5 days of the month brought most of the fog.

In the Gulf of Mexico the first fog report since spring indicated fog in a small part of the northwestern Gulf on the 20th.

OCEAN GALES AND STORMS, NOVEMBER 1936

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began November—	Time of lowest barometer November—	Gale ended November—	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Blankaholm, Swed. M. S.	Gothenburg	Portland, Maine.	50 23 N.	46 31 W.	[1] 31	4a, 1	1	28.97	SE	SW, 12	W	SW, 12	SE-W.
Peebles, Br. M. S.	Cristobal	London	[2] 19 45 N.	65 38 W.	3	4a, 3	4	29.68	ENE	ENE, 6	E	E, 7	Steady.
Braheholm, Swed. S. S.	Kristiansund	Norfolk	60 15 N.	24 48 W.	2	10a, 3	2	29.09	W	WSW, 7	WNW	W, 10	
McKeesport, Am. S. S.	Liverpool	Boston	51 00 N.	15 15 W.	4	10p, 5	9	29.05	WSW	WNW, 9	WNW	NW, 10	WSW-WNW.
Themisto, Du. S. S.	Port Talbot	Montreal	53 43 N.	27 26 W.	3	10p, 5	7	29.27	SW	WNW, 11	NW	WNW, 11	W-NW.
Braheholm, Swed. S. S.	Kristiansund	Norfolk	56 50 N.	34 35 N.	5	2p, 5	6	29.01	N	N, 12	N	N, 12	W-N.
West Hobomac, Am. S. S.	Liverpool	Beaumont	[2] 50 20 N.	10 13 W.	6	3a, 6	9	29.03	W	NW, 5	NNW	W, 9	
Fort Royal, Fr. M. S.	Rouen	Martinique	23 04 N.	48 50 W.	6	8a, 6	6	[3] 30.02	E	ESE, 8	E	ESE, 8	
Sylvafield, Br. M. S.	Cristobal	Southampton	42 25 N.	29 05 W.	6	2p, 6	10	[3] 29.85	W	NW, 7	NW	NW, 9	Steady.
Helmstrath, Br. S. S.	Quebec	London	53 28 N.	38 20 W.	6	4p, 6	9	[3] 29.40	W	W, 7	WNW	NW, 10	W-NW.
Steel Engineer, Am. S. S.	Swansea	Montreal	52 25 N.	16 55 W.	5	8p, 6	9	28.85	SW	WNW, 10	NW	WNW, 11	
Emile Francqui, Belg. S. S.	Antwerp	New York	50 04 N.	3 50 W.	7	4p, 7	9	28.81	SSW	WSW, 7	NNW	W, 11	SSW-W.
Laurent Meeus, Belg. M. S.	Amsterdam	Houston	49 34 N.	4 00 W.	6	4p, 7	9	28.95	S	SW, 9	W	W, 11	
Caledonia, Br. S. S.	New York	Moville	55 00 N.	12 00 W.	4	10a, 8	8	28.53	S	WSW, 5	N	NW, 10	WSW-N.
McKeesport, Am. S. S.	Liverpool	Boston	48 00 N.	31 15 W.	10	8p, 10	11	29.31	SW	W, 10	NW	W, 10	W-NNW.
Bergensfjord, Nor. S. S.	Bergen	New York	42 40 N.		10	11p, 10	11	29.71	ESE	W		NW, 10	ESE-NW.
Colytto, Du. S. S.	Montreal	Hull	51 08 N.	19 19 W.	10	7a, 11	12	28.89	SSE	NNW, 9	N	NNW, 11	SW-NNW.
Sarcoxie, Am. S. S.	Havre	New York	46 15 N.	15 15 W.	10	8a, 11	12	29.54	SW	W, 8	NW	WNW, 11	WSW-W.
American Banker, Am. S. S.	London	do	49 15 N.	18 55 W.	11	8a, 11	11	28.87	SW	WNW, 9	N	NNW, 11	WSW-NNW.
Emile Francqui, Belg. S. S.	Antwerp	do	50 23 N.	19 00 W.	11	8a, 11	11	28.71	NNW	NNW, 11	NNW	NNW, 11	SSW-NNW.
Laurent Meeus, Belg. M. S.	Amsterdam	Houston	45 34 N.	13 28 W.	10	11a, 11	12	29.53	SW	W, 11	NW	W, 11	
Driebergen, Du. S. S.	Wabana	Rotterdam	50 15 N.	19 30 W.	10	Noon, 11	12	[3] 29.31	SW	NNW, 11	N	NNW, 11	
Hybert, Am. S. S.	Rotterdam	New Orleans	48 15 N.	9 30 W.	11	5p, 11	12	29.04	SW	SW, 11	NW	SW, 11	SW-WSW.
Louisiane, Fr. S. S.	Antwerp	Charleston	48 57 N.	7 20 W.	11	11p, 11	13	29.00	SW	WSW, 11	NW	WSW, 11	
Steel Engineer, Am. S. S.	Swansea	Montreal	53 10 N.	42 30 W.	12	7a, 12	13	28.49	NW	SSW, 3	W	WNW, 11	SSW-NW.
Kentucky, Dan. S. S.	Newcastle	New York	53 30 N.	39 10 W.	11	10a, 12	13	28.34	SE	SW, 9	W	W, 10	SE-SW.
Sylvafield, Br. M. S.	Cristobal	Southampton	50 15 N.	1 25 W.	11	Noon, 12	12	[3] 28.81	NW	WNW, 12	NNW	WNW, 12	
Siboney, Am. S. S.	New York	Havana	34 00 N.	75 00 W.	12	10p, 12	13	29.56	ESE	SW, 12	NW	SW, 12	E-SW-NW.
American Shipper, Am. S. S.	Liverpool	Boston	51 55 N.	21 21 W.	13	5a, 13	14	29.50	S	SW, 8	W	WSW, 10	S-WSW.
Saccarappa, Am. S. S.	Antwerp	Charleston	41 53 N.	57 50 W.	13	1a, 14	14	29.03		NNE, 10	NNW	NW, 11	NNE-NNW.
McKeesport, Am. S. S.	Liverpool	Boston	45 20 N.	45 45 W.	14	Mdt, 14	15	29.00	S	W, 10	WNW	W, 10	SSW-W.
American Banker, Am. S. S.	London	New York	45 05 N.	41 41 W.	15	4a, 15	15	29.37	SW	SW, 9	NNW	NW, 10	SW-W.
Mobile City, Am. S. S.	Cristobal	Boston	25 18 N.	74 30 W.	15	7a, 15	16	29.96	NW	SW, 4	N	NNW, 9	SE-SW.
Sagaporack, Am. S. S.	Copenhagen	New York	58 44 N.	9 01 W.	15	3p, 15	15	29.08	W	SW, 9	NW	NW, 9	W-SW-NW.
I. C. White, Am. S. S.	Corpus Christi	Boston	39 12 N.	70 45 W.	15	7a, 16	17	29.32	NW	NW, 10	NW	NW, 10	WNW-NW.
American Shipper, Am. S. S.	Liverpool	do	49 10 N.	43 00 W.	16	3a, 17	17	29.02	SSE	SSW, 10	SW	SSW, 10	S-SW.
Mopan, Br. S. S.	Port Antonio	Liverpool	43 42 N.	44 05 W.	16	6p, 17	18	29.30	SSW	WSW, 7	WSW	SSW, 10	SSW-WNW.
Caledonia, Br. S. S.	Belfast	Boston	51 48 N.	38 43 W.	18	7a, 18	18	28.80	S	WNW, 10	SW	WNW, 10	S-WNW.
Do	do	do	48 38 N.	48 13 W.	19	6p, 19	20	28.88	E	WSW, 9	NW	SW, 10	SW-W.
West Kyska, Am. S. S.	Antwerp	Panama City, Fla.	45 44 N.	16 14 W.	24	1a, 24	25	29.82	NW	NNW, 7	NNE	NW, 9	WNW-NNW.
Do	do	do	39 30 N.	27 08 W.	27	8p, 26	30	29.97	NNW	NNE, 7	E	NNW, 9	W-NNE.
NORTH PACIFIC OCEAN													
Nordpol, Dan. M. S.	Shanghai	Portland, Oreg.	46 06 N.	158 30 E.	[1] 31	11p, 1	1	[3] 29.57	ESE	E, 10	E	ENE, 10	4 points.
Pres. McKinley, Am. SS.	Victoria, B. C.	Yokohama	46 30 N.	159 46 E.	2	Noon, 3	4	29.18	SSE	WNW, 7	NW	WNW, 10	NW-WNW.
Pres. Jefferson, Am. SS.	Yokohama	Victoria, B. C.	43 06 N.	156 39 E.	3	8a, 3	5	29.34	WNW	SW, 4	NW	W, 9	W-SW-NNW.
Fukuyo Maru, Jap. S. S.	Miike	Coos Bay	44 27 N.	164 31 E.	3	Noon, 4	5	29.76	W	W, 9	WNW	W, 9	W-WNW.
Nordpol, Dan. M. S.	Shanghai	Portland, Oreg.	48 39 N.	173 28 E.	3	9p, 4	5	[3] 29.13	SW	SSW, 11	WNW	SSW, 11	6 points.
Yayoi Maru, Jap. S. S.	Dairen	Astoria	48 55 N.	175 30 E.	3	Mdt, 4	5	[3] 28.80	SE	SSW, 8	WNW	WSW, 10	SSW-WSW.
Mobile City, Am. S. S.	San Francisco	Balboa	15 20 N.	94 54 W.	4	4p, 5	6	29.76	NNE	NNW, 8	WNW	NNW, 9	N-NNW.
Nordpol, Dan. M. S.	Shanghai	Portland, Oreg.	49 37 N.	170 09 W.	6	Noon, 6	6	[3] 29.60	S	S	S	S, 10	Steady.
Fukuyo Maru, Jap. S. S.	Miike	Coos Bay	47 50 N.	163 00 W.	6	8p, 9	12	29.02	SSW	SW, 6	SW	WSW, 9	SW-NW.
Nordpol, Dan. M. S.	Shanghai	Portland, Oreg.	49 44 N.	144 55 W.	7	Noon, 10	12	[3] 29.57	SW	SSW, 9	S	SSW, 9	10 points.
Somerville, Nor. M. S.	Hong Kong	Los Angeles	42 18 N.	178 24 W.	10	Mdt. 10	10	29.47	W	WNW, 8	NW	WNW, 9	W-NW.
Biyo Maru, Jap. S. S.	Muroran	New Westminster.	47 35 N.	172 15 E.	8	6p, 10	11	29.18	SSE	WNW, 10	NNW	NW, 11	W-NW.
San Ramon Maru, Jap. M. S.	Amorco	Yokohama	34 30 N.	142 40 E.	10	4p, 11	12	29.66	ENE	NE, 7	N	ENE, 10	ENE-NE.
General Lee, Am. S. S.	Yokohama	San Francisco	45 42 N.	169 05 E.	12	4p, 13	13	29.58	SE	S, 8	WSW	SE, 10	SSE-W.
Chinese Prince, Br. M. S	Los Angeles	Manila	[2] 22 46 N.	151 34 E.	14	3p, 14	14	29.78	SE	SSE, 7	S	SE, 8	SE-SSE.
Somerville, Nor. M. S.	Hong Kong	Los Angeles	41 36 N.	149 12 W.	15	7a, 15	15	28.87	S	S, 9	W	SSW, 9	SSE-SW.
Empress of Japan, Br. SS.	Victoria, B. C.	Honolulu	42 48 N.	134 42 W.	15	3a, 16	17	29.59	S	SW, 6	SSW	SSW, 10	S-SW.
Somerville, Nor. M. S.	Hong Kong	Los Angeles	41 24 N.	146 48 W.	16	5p, 16	17	29.41	S	SSE, 10	SSW	S, 11	SSE-SSW.
Kwanto Maru, Jap. M. S.	Yokohama	do	44 50 N.	150 12 W.	16	8p, 16	17	28.92	ENE	SE, 7	SW	SW, 9	ENE-SE-SW.
Biyo Maru, Jap. S. S.	Muroran	New Westminster.	50 20 N.	149 45 W.	18	2a, 17	18	29.11	SSE	NE, 4	W	W, 11	
Anna Maersk, Dan. M. S.	Yokohama	Los Angeles	46 09 N.	177 50 W.	17	7p, 17	19	28.85	S	S, 7	W	S, 10	S-SW.
Pres. Jackson, Am. S. S.	do	Victoria, B. C.	48 24 N.	174 25 E.	18	Noon, 19	19	29.40	W	W, 10	NW	W, 11	None.
Kyokuto Maru, Jap. M. S.	Kobe	San Francisco	42 47 N.	170 00 W.	18	4p, 19	21	28.99	WNW	W, 9	SW	W, 9	
Pres. Jackson, Am. S. S.	Yokohama	Victoria, B. C.	50 00 N.	164 55 W.	20	6a, 21	22	27.82	E	NE, 4	SW	E, 12	NE-N-NW.
Hikawa Maru, Jap. M. S.	Vancouver, B. C.	Yokohama	51 46 N.	148 30 W.	21	7p, 21	22	29.19	SSE	S, 9	SW	SSW, 9	S-SSW.
Michigan, Am. S. S.	Masbate, P. I.	San Francisco	29 30 N.	146 15 E.	20	6p, 22	23	29.17	NE	S, 11	NNW	SW, 12	SSE-SW.
Anna Maersk, Dan. M. S.	Yokohama	Los Angeles	44 32 N.	150 55 W.	21	4a, 21	22	29.61	SE	S, 8	SW	S, 9	SE-SW.
Liberator, Am. S. S.	Kahului, Hawaii.	Kobe	31 52 N.	142 40 E.	22	4p, 22	23	29.34	ENE	NE, 7	NW	N, 10	ENE-N.
Damsterdyk, Du. M. S.	Guayaquil	Los Angeles	14 57 N.	93 35 W.	27	6p, 27	28	29.91	NW	NW, 6	NE	NNW, 8	NW-NNW.
Kinai Maru, Jap. M. S.	Yokohama	do	43 13 N.	163 22 E.	28	11p, 29	29	29.04		E, 4		ESE, 8	
Tyndareus, Br. S. S.	do	Victoria, B. C.	46 56 N.	172 54 E.	29	5p, 30	30	29.07	SE	E, 8	W	ESE, 8	E-S-W.
Michigan, Am. S. S.	Masbate, P. I.	San Francisco	41 30 N.	177 00 E.	29	2p, 30	30	29.20	SSE	S, 10	W	S, 10	S-W.

[1] October. [2] Position approximate. [3] Barometer uncorrected.

NORTH PACIFIC OCEAN, NOVEMBER 1936

By WILLIS E. HURD

Atmospheric pressure.—While the situation relative to the position of high- and low-pressure areas on the North Pacific Ocean during November 1936 was practically normal, the departures from normal barometer were unusually irregular, especially over northern waters. In the Aleutian region, where a strong cyclone persisted largely throughout the month, average pressures were 0.10 to 0.17 inch below the normal, while at Juneau the departure from normal was +0.18; and at Tatoosh Island, +0.31, which is an extraordinarily high value for that locality. The plus departure was also unusually high, +0.16 at Naha, in the Nansei Islands, Japan. (See table 1 for further pressure data.)

Anticyclonic conditions prevailed off the Pacific coast of the United States, and mostly, except for breaks due to passing cyclones, southwestward to Midway Island and on westward to the China coast.

The lowest corrected pressure of the month, 27.82 inches, was reported by the American steamship *President Jackson*, in 50°00′ N., 164°55′ W., on the 21st.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, November 1936, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	30.05	+0.06	30.36	2	29.50	22
Dutch Harbor	29.42	−.17	30.04	17	28.52	21
St. Paul	29.47	−.12	30.12	13	28.64	1
Kodiak	29.46	−.10	30.22	4, 26	28.66	22
Juneau	29.94	+.18	30.48	24	29.06	17
Tatoosh Island	30.28	+.31	30.58	30	29.92	16
San Francisco	30.14	+.05	30.46	3	29.94	1
Mazatlan	29.90	+.01	30.08	28	29.82	9
Honolulu	29.99	−.03	30.19	18	29.69	23
Midway Island	30.16	+.08	30.34	17, 18, 19	29.96	26
Guam	29.79	−.07	29.90	29	29.66	18, 19
Manila	29.84	+.01	29.94	23, 24	29.72	6
Naha	30.06	+.16	30.18	24	29.92	1
Chichishima	29.98	.00	30.20	25	29.32	21
Urakawa	30.07	----------	30.54	20	29.56	28

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Extratropical cyclones and gales.—Stormy weather set in along the northern steamship routes during November, and on a number of days gales of great severity occurred, particularly along that part of the routes lying between longitudes 165° E. and 140° W. Within this region, to the northward of the fortieth degree of latitude, gales of force 11 to 12 were reported on the 4th, 10th, 16th, 18th, 19th, 20th, and 21st, and of force 10 on several other dates.

Few storms of consequence entered the ocean from Asia this month, and most of the cyclones merging in the well-developed Aleutian LOW were of oceanic origin. While most of these northern storms affected middle latitudes, yet few gales were reported in connection with them to the southward of the fortieth parallel, and such of the few as were noted by ships' observers did not exceed 8 in force.

In upper east longitudes most of the severe weather occurred before the 20th, with the highest winds, force 11, reported by the Danish motorship *Nordpol* on the 4th; by the Japanese steamship *Biyo Maru* on the 10th; and by the American steamship *President Jackson* on the 19th, all near 48° N., 172°–175° E.

In west longitudes the heaviest gales occurred within the period 16–21st, with few high winds in excess of force 8 or 9 preceding the 16th, and none in excess of force 8 reported following the 22d. On two of these dates winds of force 11 were encountered, first, by the Norwegian motorship *Somerville*, on the 16th, in 41°24′ N., 146°48′ W., and second, by the Japanese steamship *Biyo Maru*, on the 18th, in 50°20′ N., 149°45′ W. On the 20th and 21st the eastbound steamship *President Jackson*, which had already weathered the severe gale of the 19th south of the western Aleutians, became involved in the heavier winds of the deepest cyclone of the month centered southeast of the eastern Aleutians. The ship on the 20th proceeded into the teeth of an easterly hurricane, and approximately 24 hours later was in a westerly gale of similar force, lowest barometer 27.82 inches.

Subsequently to the 22d the roughness of the weather subsided generally over the North Pacific, and on only two dates thereafter, the 24th and the 30th, were isolated gales of as high force as 10 met with in northern waters.

The west coast of the United States and Canada, largely dominated by anticyclonic conditions in November, was singularly free of high winds, according to ships' observations. Only one vessel encountered gales within a day's journey of the American extratropical coast. This was the British steamship *Empress of Japan*, which, after leaving Victoria, British Columbia, on a voyage toward Honolulu, met a south gale of force 8 on the 15th, and a southwesterly whole gale on the 17th, the latter occurring in 42°48′ N., 134°42′ W.

Tropical gales and cyclones.—In the American Tropics, northers of force 7 occurred on the 23d; of force 8 on the 27th and 28th; and of force 9 on the 5th, in the Gulf of Tehuantepec.

On November 18 strong northeast trades (force 7) were reported east of the Hawaiian Islands and in low latitudes northwest of Palmyra Island.

On the 9th and 10th of the month a tropical cyclone raged over the Marshall Islands. Jaluit, the port of entry for Nauru Island, near 6° N., 170° E., reported a south gale of force 9, barometer 29.66, at p. m. observation of the 9th. On the morning of the 11th the wind had risen to force 11, with barometer at 29.56. At p. m. of the 11th the wind had shifted to southwest, force 9, with rising pressure. No further details of the storm are available.

Subjoined is a report by the Reverend Bernard F. Doucette, of the Weather Bureau, Manila, P. I., descriptive of three typhoons and one depression which occurred on the southwestern Pacific during Novmber 1936. These, it is to be noted, do not include the typhoon of the Marshall Islands, mentioned in the preceding paragraph.

In connection with the typhoon of November 18–23, described by Father Doucette, the following additional data are derived from our ships' reports. On the 22d the American steamship *Liberator*, on the west side of the storm center in 31°52′ N., 142°40′ E., experienced a whole gale from the north, lowest barometer 29.34. The American steamship *Michigan*, Masbate, P. I., toward San Francisco, rode across the north quadrants of the storm on the 20th and 21st, encountering gales of force 8–10 from northeast to east. The wind changed to southeast on the morning of the 22d, then to south with an increase to force 11 about 6 p. m., lowest barometer 29.17, in 29°30′ N., 146°15′ E. Two hours later the ship was in a southwesterly hurricane, which lasted until midnight. Thereafter, with rapidly rising barometer, the wind abated. The typhoon then passed northward to the eastward of

Honshu and Hokushu Islands with great speed and lessened severity, and by the 24th had joined with a depression over the Sea of Okhotsk.

Fog.—There was little fog recorded on the open reaches of the Pacific this month, reports showing that it occurred only on the 1st and 9th, in upper east longitudes. In coastal waters of California there were 9 days with fog and in those of Washington, 8 days. Press reports from Vancouver state that shipping, owing to dense fog, was tied up at the water front from the 25th to 27th. Fog formed on the 9th near the Gulf of Tehuantepec.

TYPHOONS AND DEPRESSIONS OVER THE FAR EAST NOVEMBER 1936

Rev. BERNARD F. DOUCETTE, S. J.

[Weather Bureau, Manila, P. I.]

There were three typhoons and one depression over the ocean regions east of the Philippines during November 1936. In addition, during November 10 to 12, a mild depression formed over the eastern Caroline Islands, moved west-northwest, threatened to develop, but finally disappeared, apparently of minor importance.

Typhoon, November 1 to 8.—A depression moved from the eastern Caroline Islands westward to longitude 135° (Nov. 4), and then inclined to the northwest, intensifying at the same time. On November 6 it was central in latitude 13°30′ N., longitude 127°30′ E., strong enough to be classified as a typhoon, from which position it moved westward and entered the Philippines south of Virac, Cataduanes Islands, and Legaspi, Albay Province (Nov. 6 and 7). When it was close to the archipelago, it was found to be a small typhoon of moderate intensity, decreasing in strength as it passed over the northern Visayan Islands. It passed over the Verde Island Passage into the China Sea, where it disappeared on November 8.

The November 6, 4 p. m. observation at Atimonan, Tayabas Province, was north-northwest wind force 7 with barometer 752.8 mm (29.638 inches). At the same time, Odiongan, Romblon Province, reported southwest winds, force 5, and a pressure of 753.7 mm (29.673 inches). The estimated pressure at the center of the disturbance was about 750 mm (29.528 inches).

Typhoon, November 5 to 12.—On November 2, the steamship *Thistlebrae* encountered a small center near latitude 14° N., longitude 155° E., with winds of hurricane force veering from northeast (Nov. 2, 8 a. m.) to south (Nov. 3, midnight), the minimum barometer being 735.4 mm (28.953 inches). After November 2 no reports were received from the neighborhood and the typhoon appearing in the regions represented by the weather map, November 5, is probably the same center reported by the steamship *Thistlebrae*. On this day, about 300 miles northeast of Guam, there was a definite center and apparently a typhoon, as far as the observations received from Guam and Saipan could indicate. It moved westward, November 5 to 8, then recurved to the northeast, moving from latitude 17°30′ to 24° N., between the meridians 134° and 130° E. It inclined to the north-northeast on November 11 and passed beyond the region of observation, November 12. On November 11, the afternoon observation reported from the Bonin Islands was south-southwest winds, force 4, barometer 754.5 mm (29.705 inches).

Typhoon, November 18 to 23.—A depression formed over the eastern Caroline Islands and finally moved westward, intensified, and appeared as a typhoon about 250 miles south-southeast of Guam. Here it abruptly changed its course to the north, inclined slightly to the north-northwest as it passed about 50 miles east of Guam, moving quite rapidly. It then proceeded along a west-northwest course for one day (Nov. 20) and recurved to the north-northeast the afternoon of November 21. The next morning, it was central about 180 miles west-southwest of the Bonins. Its motion along a northeasterly course brought it beyond the region of observation on the afternoon of November 23.

Along the course of this typhoon, the observations which can be used to judge its intensity are as follows: The lowest barometer reading at Guam was 748.5 mm (29.468 inches) with south winds, force 4, 3 p. m. November 19. On November 22, 6 a. m. the Bonin Islands had a pressure of 746.0 mm (29.370 inches) with winds of force 8 from the south-southeast. At 2 p. m. of the same day, 743.0 mm (29.252 inches) with southwest winds of force 8 were reported from the same location. The typhoon apparently weakened November 21 and then quickly intensified the next day.

Depression, November 25 to 30.—A mild depression formed east of Mindanao, moved west-northwest to the Visayan Islands, where it changed its course to the southwest for a short time, bringing the center to the Sulu Sea. From here it proceeded across the northern part of Palawan Island to the China Sea where it disappeared.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, November 1936

[For description of tables and charts, see REVIEW, January, p. 29]

Section	Temperature: Section average	Temperature: Departure from the normal	Monthly extremes: Station	Highest	Date	Station	Lowest	Date	Precipitation: Section average	Precipitation: Departure from the normal	Greatest monthly: Station	Amount	Least monthly: Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	53.3	−1.1	Pushmataha	90	[1] 2	Valley Head	15	28	1.72	−1.69	Belgreen	4.00	Valley Head	0.51
Arizona	52.4	+.1	Agua Caliente	95	[1] 15	Bright Angel	5	3	.87	−.15	Paradise	3.46	3 stations	.00
Arkansas	48.5	−2.9	3 stations	87	[1] 2	Gilbert	12	27	3.00	−.69	Crossett	6.41	Gilbert	.10
California	52.7	+.4	El Cajon	94	18	Tule Lake	3	[1] 28	.10	−2.31	Cuyamaca	1.50	74 stations	.00
Colorado	35.7	+.5	Lamar	83	27	Hermit (near)	−22	3	.33	−.46	Pagosa Springs (near).	3.70	9 stations	.00
Florida	63.8	−1.4	Cedar Keys	92	4	Perry	18	28	1.53	−.65	Belle Glade	9.17	3 stations	.00
Georgia	53.4	−1.2	3 stations	89	[1] 2	Blairsville	9	28	1.35	−1.31	Americus	3.35	Lumber City	.00
Idaho	32.0	−3.5	Hollister	70	[1] 11	Pelton Ranch	−13	3	.17	−1.88	Preston	1.05	14 stations	.00
Illinois	39.5	−2.0	Carbondale	79	2	Jacksonville	6	27	2.30	−.45	Shawneetown	5.03	Galva	.45
Indiana	38.4	−3.9	Rome	80	2	Marion	7	27	3.58	+.51	Huntingburg	7.03	Whiting	1.05
Iowa	35.5	−.8	Oakland	77	1	Sheldon	−5	8	.66	−.95	Wapello	1.94	Tingley	.08
Kansas	43.1	−.2	3 stations	80	1	Tribune	7	3	.18	−1.11	Pittsburg	4.10	31 stations	.00
Kentucky	42.9	−3.6	2 stations	81	[1] 2	2 stations	10	[1] 27	3.50	+.03	Henderson	5.62	Pikeville	1.82
Louisiana	56.3	−2.7	3 stations	92	3	Tallulah	22	27	3.74	−.11	Schriever	6.00	Port Eads	1.47
Maryland-Delaware	43.2	−2.0	Cheltenham, Md	82	3	Sines, Md	4	30	.99	−1.47	Friendsville, Md	2.70	Edgewood, Md	.52
Michigan	32.3	−4.7	4 stations	67	2	East Jordan	−14	30	1.43	−1.05	Ironwood	4.56	Mount Pleasant	.28
Minnesota	26.2	−3.4	Faribault	69	20	Redby	−20	7	1.00	−.16	Reads	2.40	Argyle	.16
Mississippi	52.6	−2.6	Forest	90	2	2 stations	19	[1] 27	2.90	−.72	Vicksburg	5.23	Philadelphia	1.20
Missouri	42.2	−2.2	5 stations	79	[1] 1	Greenville	0	27	1.89	−.77	Jefferson City	4.99	Unionville	T
Montana	31.6	−.5	Geraldine (near)	82	19	2 stations	−26	[1] 6	.35	−.61	Ashland (near)	1.18	Trout Creek (near)	.02
Nebraska	37.4	+.1	Beatrice	77	20	Gordon	−11	8	.28	−.50	Merriman	2.25	9 stations	.00
Nevada	40.2	+.3	Logandale	83	13	Sharp	−3	3	.09	−.55	Sharp	.75	18 stations	.00
New England	34.0	−4.0	Waterbury, Conn	76	3	East Barnet, Vt	−14	28	2.04	−1.39	Somerset, Vt	3.97	2 stations	1.05
New Jersey	41.1	−2.5	Hammonton	80	4	Layton	3	28	1.18	−2.00	Culvers Lake	3.04	Tuckerton	.40
New Mexico	40.7	−1.9	Carlsbad Cavern	83	1	Therma	−13	3	.47	−.19	Culberson Ranch	5.16	33 stations	.00
New York	34.1	−3.9	Scarsdale	78	2	Chasm Falls	−14	30	2.74	−.27	Jamestown	6.03	Hicksville	.65
North Carolina	48.8	−1.2	Fayetteville	86	3	Mount Mitchell	0	28	2.15	−.48	Smithfield	4.87	Parker	.84
North Dakota	28.0	−1.4	Watford City	69	19	Willow City	−28	7	.34	−.26	Napoleon	1.10	Hettinger	.02
Ohio	37.8	−3.6	2 stations	74	2	Holgate	2	27	2.66	−.08	Fernbank	4.95	Put-in-Bay	.96
Oklahoma	48.0	−1.8	Ardmore	85	1	Hooker	12	4	.51	−1.51	Tuskahoma	3.17	15 stations	.00
Oregon	36.9	−3.6	Mitchell	89	22	Austin	−24	1	.20	−3.47	Astoria	1.93	10 stations	.00
Pennsylvania	38.6	−2.7	6 stations	78	[1] 3	2 stations	2	28	2.40	−.47	Westford	5.53	New Park	.59
South Carolina	52.0	−1.7	Kingstree	88	3	do	12	28	1.77	−.56	Camden	3.99	Summerville	.42
South Dakota	32.6	−.3	Faith	78	20	Canton	−8	8	.83	+.19	Mellette	2.60	Strool	T
Tennessee	45.9	−2.7	Loudon	85	4	2 stations	7	28	3.07	−.52	Sky Harbor	5.45	Elizabethton	.79
Texas	53.5	−3.6	Encinal	96	2	Muleshoe	13	24	1.37	−.81	Bon Wier	4.93	14 stations	.00
Utah	35.6	−1.8	St. George	76	[1] 15	Silver Lake	−13	3	.58	−.36	High Line City Creek	2.01	7 stations	.00
Virginia	45.0	−1.6	Tappahannock	84	4	Mountain Lake	6	28	1.11	−1.28	Wallaceton	3.33	2 stations	.34
Washington	36.9	−2.8	2 stations	72	18	Deer Park (near)	−4	2	.62	−4.59	Clearwater	3.53	3 stations	.00
West Virginia	41.3	−2.0	Hinton	85	3	Rainelle	1	28	2.54	−.22	Point Pleasant	4.19	Kearneyville	.59
Wisconsin	30.4	−2.9	Arlington	70	2	Long Lake	−20	30	.91	−.94	Iron River	2.65	Milwaukee Airport	.14
Wyoming	30.7	−1.0	Pine Bluffs	75	16	2 stations	−30	3	.49	−.21	Elk Mountain	1.52	Foxpark	T
Alaska (October)	34.9	+4.1	Treepoint	72	1	Barrow	−14	30	6.03	+2.53	Cordova	45.13	Barrow	.05
Hawaii	71.7	+.1	2 stations	92	[1] 2	Kanalohuluhulu	38	26	5.87	−1.85	Piihonua	40.00	Ka Lae	.00
Puerto Rico	75.4	−1.0	Coloso	96	27	Guineo Reservoir	40	24	4.42	−3.00	La Mina (El Yunque).	15.19	Santa Rita	.04

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, November 1936*

[Compiled by Annie E. Small, by official authority U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							37.2	-2.3										73	1.70	-1.5										6.2		
Eastport	76	67	85	29.85	29.94	-0.07	34.4	-2.3	60	3	42	7	28	27	27	33	30	85	2.20	-1.1	16	7,934	nw.	32	nw.	10	3	5	22	8.1	7.5	1.0
Greenville, Me.	1,070	6	40	28.75	29.95		25.6		58	4	34	-5	28	18	30	24	23		2.06		16	5,045	se.	26		10	4	4	22		15.6	
Portland, Me.	103	82	117	29.85	29.98	-.03	35.9	-2.1	64	4	44	11	28	28	29	30	23	64	1.75	-1.7	13	6,144	n.	29	nw.	16	12	8	10	5.0	2.9	1.2
Concord	289	60		29.67	29.99	-.07	33.5	-4.2	71	3	44	1	28	23	37				2.25	-.8	9		nw.				8	11	11		3.5	.0
Burlington	403	11	48	29.53	29.99	-.06	31.2	-5.1	68	3	39	1	28	23	29	28	24	78	2.30	-.4	16	8,800	s.	34	s.	17	2	4	24	8.0	11.8	1.5
Northfield	876	12	60	29.02	30.00	-.05	29.4	-3.4	70	3	39	-8	28	20	37	26	23	80	2.23	-.7	18	6,015	s.	27	sw.	14	2	10	18	7.6	8.4	3.2
Boston [1]	29	31	50	29.96	29.99	-.06	39.5	-2.5	75	3	48	13	30	32	34	34	28	67	1.33	-2.0	9	8,102	w.	31	nw.	16	11	9	10	5.5	4.4	T
Nantucket	12	14	90	30.00	30.01	-.04	43.4	-1.0	65	3	50	18	18	37	32	40	35	74	1.81	-1.4	12	11,378	w.	46	sw.	17	7	7	16	6.4	.2	.0
Block Island	26	11	46	29.98	30.01	-.05	43.1	-1.5	65	3	50	17	30	36	31	40	36	76	1.44	-2.2	8	13,465	nw.	51	nw.	16	8	10	12	6.0	.7	.0
Providence	160	215	251	29.84	30.02	-.05	39.4	-1.0	72	3	48	13	30	31	33	35	28	66	1.05	-2.0	9	8,601	nw.	41	nw.	16	12	8	10	5.0	3.7	.2
Hartford	159	70	104	29.85	30.03	-.05	39.0	-.5	72	3	47	13	30	31	32				1.21	-2.3	8	6,728	nw.	34	nw.	16	11	10	9	5.0	2.8	T
New Haven	106	74	153	29.93	30.04	-.03	40.7	-1.3	71	3	49	15	30	33	33	35	29	66	1.09	-2.3	7	7,235	nw.	31	nw.	16	11	10	9	5.2	3.5	T
Middle Atlantic States							43.2	-1.7										66	1.28	-1.3										5.9		
Albany	97	97	112	29.93	30.04	-.04	37.2	-2.1	72	3	45	8	30	29	34	32	25	64	2.16	-.6	10	5,937	s.	26	s.	28	5	7	18	6.9	4.1	T
Binghamton	871	57	79	29.09	30.04	-.05	35.6	-3.1	71	3	44	3	30	27	30				2.92	+.5	15	5,302	nw.	25	nw.	16	3	5	22	8.0	6.1	2.0
New York	314	415	454	29.71	30.06	-.03	42.4	-1.8	73	3	50	16	30	35	30	37	31	67	1.06	-1.9	9	12,389	nw.	60	nw.	16	10	10	10	5.3	1.8	.0
Harrisburg	374	94	104	29.67	30.09	-.02	40.6	-2.2	75	3	48	16	30	33	34	35	28	64	1.35	-.9	7	5,972	w.	27	nw.	16	3	10	17	7.2	1.5	.0
Philadelphia	114	174	367	29.96	30.09	-.01	43.5	-2.2	77	4	51	20	19	36	30	38	30	63	.69	-2.0	5	10,285	sw.	40	nw.	18	10	10	10	5.6	T	.0
Reading	323	283	306	29.73	30.10		41.6	-.9	75	3	49	17	30	34	33	36	29	64	1.17	-1.6	8	9,042	nw.	40	nw.	16	6	13	11	6.2	1.5	.0
Scranton	805	72	104	29.17	30.06	-.03	37.6	-2.9	75	3	45	10	30	30	30	33	27	70	2.59	-.2	10	5,319	sw.	29	nw.	18	2	15	13	6.9	3.8	T
Atlantic City	52	37	172	30.02	30.08	-.02	45.1	-.5	67	4	53	18	19	38	29	40	34	66	.67	-2.2	7	12,034	w.	43	w.	16	9	6	15	5.9	.1	.0
Sandy Hook	22	10	57	30.03	30.05		43.1	-2.7	73	3	50	20	18	36	28	38	34	73	1.19	-2.1	6	12,113	nw.	53	nw.	18	9	8	13	5.5	T	.0
Trenton	190	88	106	29.86	30.07		41.2	-3.2	75	3	49	16	30	33	30	36	29	65	.75	-2.0	6	7,762	nw.	32	nw.	16	13	8	9	4.9	.2	.0
Baltimore	123	100	215	29.96	30.09	-.02	45.6	-.7	78	4	54	20	19	38	30	39	31	61	.79	-1.8	7	8,076	sw.	35	nw.	16	7	14	9	5.5	T	.0
Washington	112	62	85	29.97	30.10	-.02	45.0	-.2	79	4	53	19	19	37	32	38	31	61	.76	-1.6	5	5,408	nw.	28	nw.	16	9	12	9	5.3	T	.0
Cape Henry	18	8	54	30.08	30.10		50.3	-1.8	82	4	58	24	28	43	31	45	40	70	1.69	-.7	6	9,911	sw.	43	nw.	15	11	13	6	5.2	.0	.0
Lynchburg	686	148	184	29.38	30.14	+.01	46.2	-1.0	76	4	56	20	28	36	34	40	33	66	.66	-1.7	4	5,811	sw.	32	nw.	15	13	6	11	4.9	T	.0
Norfolk	91	80	125	30.03	30.13	+.02	50.4	-1.0	81	4	58	25	28	43	28	44	39	71	1.87	-.3	10	7,658	n.	30	nw.	15	8	8	14	6.2	T	.0
Richmond	144	11	52	29.97	30.13	+.01	47.6	-.7	81	3	58	20	28	38	36	40	34	67	.92	-1.3	7	6,464	sw.	27	nw.	4	11	10	9	4.9	.0	.0
Wytheville	2,304	49	55		30.13	.00	41.2	-1.8	74	3	51	15	28	32	32			72	.60	-1.5	7	6,140	w.	32	w.	28	10	10	10		.7	.0
South Atlantic States							53.5	-0.7										73	1.79	-0.6										4.7		
Asheville	2,253	89	104	27.77	30.18	+.04	44.9	-.2	73	2	56	12	28	34	42	38	33	70	1.15	-1.1	8	6,753	nw.	27	nw.	15	11	10	9	5.4	.8	.0
Charlotte	779	63	86	29.30	30.15	+.02	49.6	-1.0	78	4	59	22	28	40	31	42	36	66	1.52	-1.0	6	5,613	sw.	22	nw.	15	13	8	9	4.8	T	.0
Greensboro	886	6	56	29.17	30.15		45.8		76	4	56	17	28	36	35	39	35	76	1.51		7	6,418	sw.	26	nw.	15	12	9	9	4.6	.0	.0
Hatteras	11	5	50		30.11	.00	55.8	-.5	79	4	62	33	28	50	23	51	48	77	1.98	-1.5	6	11,036	n.	42	nw.	15	12	9	9	4.7	.0	.0
Raleigh	376	103	146	29.72	30.13	.00	50.2	-.8	80	3	60	23	28	41	31	44	40	75	2.53	+.2	7	6,858	w.	27	nw.	15	17	5	8	3.9	T	.0
Wilmington	72	73	107	30.07	30.15	+.03	54.5	-1.5	80	4	64	26	28	46	32	48	44	78	3.03	+1.1	7	6,540	n.	28	nw.	15	13	9	8	4.4	.0	.0
Charleston	48	11	92	30.09	30.14	+.02	57.2	-.9	80	4	65	30	28	50	28	51	46	73	.83	-1.3	5	7,607	n.	27	ne.	19	13	6	11	4.8	.0	.0
Columbia, S. C.	347	70	91	29.77	30.17	+.05	53.2	-.8	80	2	63	22	28	44	34	45	39	67	2.58	+.6	8	6,308	ne.	24	w.	15	14	8	8	4.3	.0	.0
Greenville, S. C.	1,039	139					49.6	.0	77	4	60	20	28	39	37				1.34	-1.8	7		ne.				11	11	8		T	.0
Augusta	182	62	77	29.95	30.14	+.01	54.2	-.3	82	4	64	25	28	44	37	47	42	72	2.64	+.2	7	4,634	nw.	21	nw.	15	11	9	10	4.7	.0	.0
Savannah	65	73	152	30.08	30.15	+.03	58.2	-.3	83	3	67	28	28	49	29	51	47	75	1.25	-.8	6	7,487	n.	32	nw.	15	15	4	11	4.6	.0	.0
Jacksonville	43	86	110	30.09	30.14	+.04	60.6	-1.6	86	4	69	30	28	52	30	54	50	76	.79	-1.2	6	5,748	n.	22	nw.	22	9	8	13	5.6	.0	.0
Florida Peninsula							71.1	+0.1										76	2.14	-0.1										5.0		
Key West	22	10	64	30.02	30.04	+.02	74.9	+.6	88	13	80	54	28	70	16	68	66	78	1.38	-.8	8	7,582	ne.	21	n.	22	12	13	5	4.6	.0	.0
Miami	25	124	168	30.04	30.07	+.01	72.0	+.2	85	13	78	44	28	66	25	65	62	73	4.35	+1.4	13	7,441	e.	25	ne.	5	5	15	10	5.9	.0	.0
Tampa	35	88	197	30.07	30.11	+.03	66.5	-.4	86	4	75	33	28	58	31	59	56	78	.70	-1.0	3	8,308	ne.	36	nw.	22	14	10	6	4.4	.0	.0
Titusville	43	5	36	30.05	30.10		65.2		89	4	75	35	28	55	31				4.28		5		nw.				16	10	4		.0	.0
East Gulf States							55.4	-1.2										71	2.25	-1.0										4.8		
Atlanta [1]	976	5	53	29.12	30.16	+.03	50.1	-2.0	81	3	60	20	28	40	34	45	39	74	2.33	-.7	7	6,674	nw.	29	nw.	15	13	3	14	5.1	T	.0
Macon	370	79	87	29.77	30.17	+.04	53.8	-.4	81	3	64	23	28	43	37	47	41	71	2.68	+.2	7	5,104	nw.	25	nw.	21	15	6	9	4.5	.0	.0
Thomasville	273	49	58	29.86	30.16	+.04	57.7	-.8	86	3	68	28	28	48	34	50	46	74	.08	-2.6	3		ne.				14	4	12		.0	.0
Apalachicola	35	11		30.11	30.15		60.4	-.9	82	4	69	33	28	52	28	54	50	76	.39	-2.7	4	6,263	n.	26	n.	22	15	5	10	4.5	.0	.0
Pensacola	56	149	185	30.11	30.17	+.06	59.2	-1.0	80	3	67	35	27	51	33	52	47	71	2.72	-1.0	4	8,799	n.	30	w.	26	14	8	8	4.3	.0	.0
Anniston	741	9					51.6	-.3	82	3	62	21	28	41	39				1.17	-2.1	6		nw.				12	9	9		.0	.0
Birmingham	700	11	48	29.40	30.19	+.07	51.4	-2.5	82	2	62	24	27	41	38	44	39	70	1.62	-1.7	7	4,998	n.	20	se.	3	14	6	10	4.7	.0	.0
Mobile	57	86	105	30.11	30.18	+.07	57.6	-1.0	82	2	67	30	28	48	29	50	45	72	2.86	-.8	6	7,238	n.	27	nw.	4	13	6	11	5.0	.0	.0
Montgomery	218	92	105	29.94	30.20	+.08	55.5	-.3	82	2	66	27	28	45	33	47	41	68	2.10	-1.1	6	5,162	n.	22	w.	26	14	4	12	5.0	.0	.0
Meridian	375	67	92	29.79	30.20	+.08	52.6	-1.6	85	2	64	24	28	41	39	45	40	71	2.80	-.5	7	4,247	ne.	20	sw.	26	13	6	11	4.9	.0	.0
Vicksburg	247	65	73	29.95	30.22	+.10	54.0	-2.6	84	1	64	30	5	44	35	46	39	66	5.23	+1.5	8	4,892	n.	21	nw.	26	13	6	11	4.9	.0	.0
New Orleans	53	76	84	30.13	30.19	+.09	60.4	-1.2	89	3	69	40	26	52	34	53	48	70	3.06	-.1	6	5,255	ne.	18	ne.	4	12	9	9	5.0	.0	.0
West Gulf States							54 8	-2.9										70	1.95	-1.0										5.2		
Shreveport	249	92	227	29.96	30.24	+.13	54.3	-1.7	86	2	64	30	4	44	41	46	40	67	2.34	-1.3	6	7,687	ne.	30	nw.	25	16	5	9	4.0	.0	.0
Bentonville	1,303	12	38	28.80	30.20	+.09	44.5	-2.2	75	1	56	22	4	33	36				2.31	-.8	2	4,981	sw.	24	nw.	27	17	6	7		T	.0
Fort Smith	457	79	94	29.73	30.22	+.11	47.8	-3.2	79	1	58	28	4	37	35	41	35	65	1.09	-1.8	4	5,686	sw.	28	nw.	26	17	4	9	3.8	T	.0
Little Rock	357	94	102	29.84	30.23	+.11	49.6	-2.5	82	2	59	27	27	40	33	42	35	64	3.67	-.5	7	6,314	nw.	27	nw.	26	18	3	9	4.1	T	.0
Austin	605	136	148	29.58	30.22		55.1	-3.4	87	2	65	30	5	46	39	48	43	72	2.30	.0	8	5,008	n.	27	ne.	3	7	12	11	5.9	.0	.0
Brownsville	57	88	96	30.09	30.15		63.8	-3.4	85	3	71	42	4	56	42	57	54	77	.45	-1.5	5	7,447	nw.	33	nw.	3	2	9	19	7.5	.0	.0
Corpus Christi	20	11	78	30.17	30.19	+.12	61.2	-3.1	84	2	68	38	4	54	35	55	51	76	.47	-1.5	8	7,036	n.	29	n.	3	5	9	16	7.2	.0	.0
Dallas	512	220	227	29.66	30.22		52.2		83	2	61	29	4	44	37	46	39	66	.74	-1.8	7	7,805	n.	34	s.	2	14	6	10	4.5	.0	.0
Fort Worth	679	92	110	29.51	30.24	+.14	52.4	-3.1	85	2	62	30	22	43	39				.46	-2.1	6	6,490	n.	33	n.	2	18	2	10	4.0	.0	.0
Galveston	54	106	114	30.14	30.20	+.11	59.9	-3.4	81	2	66	38	4	53	38	55	52	70	2.74	-.6	5	7,402	n.	32	nw.	4	14	7	9	5.0	.0	.0
Houston	138	202	314	30.06	30.21		57.4	-3.6	84	2	67	32	4	48	41				2.15	-1.7	9	8,873	n.	32	n.	3	12	6	12	5.4	.0	.0
Palestine	510	64	72	29.69	30.23	+.12	54.1	-3.1	84	2	64	28	4	44	44	46	40	67	3.02	-.4	6	4,884	n.	20	s.	2	15	5	10	4.3	.0	.0
Port Arthur	34	58	66	30.16	30.20		58.1		82	2	68	34	4	48	44	51	46	72	3.27	+.2	6	6,941	n.	27	nw.	3	11	9	10	5.1	.0	.0
San Antonio	693	242	301	29.47	30.19	+.11	57.8	-2.5	88	2	66	31	4	49	35	49	42	64	2.17	+.3	6	7,479	n.	35	n.	3	3	13	14	6.9	.0	.0

[1] Observations taken at airport.

TABLE 1.—*Climatological data for Weather Bureau stations, November 1936*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
Ohio Valley and Tennessee							**42.2**	**−3.0**										**72**	**3.21**	**0.0**										**5.2**		
Chattanooga	762	71	214	29.36	30.19	+0.05	49.4	−1.0	80	2	59	20	28	40	36	42	36	65	1.90	−1.5	8	6,290	w.	29	nw.	15	13	6	11	4.9	T	0.0
Knoxville	995	66	84	29.10	30.18	+.05	47.0	−.9	81	3	57	20	28	37	34	41	36	74	1.20	−1.9	8	4,564	w.	20	nw.	15	12	8	10	4.9	0.6	.0
Memphis	399	78	86	29.77	30.21	+.09	48.7	−3.0	81	2	57	25	27	40	40	42	35	65	3.64	−.6	6	6,050	sw.	30	nw.	26	16	6	8	3.9	.2	.0
Nashville	546	168	188	29.62	30.21	+.09	46.0	−3.0	79	2	56	20	27	36	35	40	35	71	3.52	.0	5	6,621	nw.	34	s.	2	11	10	9	4.9	1.3	.0
Lexington	989	6					41.1	−3.7	75	2	51	16	27	31	34				2.65	−.7	8		sw.				15	9	6		6.1	.0
Louisville	525	188	234	29.59	30.19	+.07	42.0	−4.7	78	2	51	18	27	33	36	37	32	71	4.11	+.5	4	8,304	sw.	30	nw.	15	15	6	9	4.2	1.6	.0
Evansville	431	76	116	29.71	30.19	+.07	42.6	−4.0	75	2	52	20	27	34	34	37	31	69	4.62	+.9	7	7,036	nw.	34	s.	2	13	11	6	4.3	7.1	.0
Indianapolis	822	194	230	29.24	30.15	+.05	39.4	−2.9	69	2	47	18	27	32	29	34	28	69	4.58	+1.2	4	8,598	w.	31	nw.	15	10	8	12	5.6	T	.0
Terre Haute	575	63	149	29.52	30.15		40.6		71	2	49	21	27	32	32	35	30	73	3.96	+.6	4	7,562	sw.	27	sw.	2	14	5	11	4.7	T	.0
Cincinnati	627	11	51	29.46	30.17	+.05	40.1	−2.4	72	2	49	20	19	31	33	35	30	75	3.95	+1.1	5	6,218	sw.	24	w.	14	12	7	11	5.1	8.9	.0
Columbus	822	90	210	29.24	30.14	+.03	38.3	−3.6	66	2	46	16	27	31	28	34	29	72	2.95	+.2	5	7,307	s.	31	sw.	17	10	6	14	6.0	3.6	.0
Dayton	900	58	153	29.16	30.17		39.0	−3.0	70	2	47	21	30	31	33				3.36	+.5	4	6,940	sw.	28	sw.	17	10	7	13	5.4	7.3	.0
Elkins	1,947	59	78	28.05	30.17	+.05	38.6	−1.7	76	3	49	14	19	28	41	33	29	77	2.61	−.2	12	5,221	w.	28	w.	14	4	12	14	6.9	1.8	.0
Parkersburg	637	77	84	29.50	30.18	+.06	40.9	−2.9	71	3	50	19	27	32	35	36	32	77	2.56	.0	6	5,079	sw.	27	nw.	15	8	10	12	5.8	.1	.0
Pittsburgh [1]	1,273	39	54	28.70	30.09	−.01	38.2	−5.0	74	3	46	14	30	30	30	33	28	73	2.65	+.4	9	9,244	sw.	34	nw.	16	6	8	16	6.6	1.2	.0
Lower Lake Region							**35.8**	**−3.5**										**76**	**2.67**	**−0.1**										**7.5**		
Buffalo	768	243	280	29.18	30.04	−.01	35.0	−4.4	67	3	41	10	27	29	26	32	29	79	1.76	−1.3	15	13,342	w.	54	sw.	17	4	7	19	7.7	9.7	3.5
Canton	448	10	61	29.50	29.99		30.0	−3.9	67	3	38	−8	30	22	32	28	25	82	2.70	−.5	16	7,066	sw.	32	sw.	17	4	7	19	7.8	12.3	2.0
Ithaca	836	77	100	29.11	30.04		34.6	−4.0	69	3	42	3	30	27	29	31	27	74	2.78	+.4	14	8,185	nw.	31	nw.	16	3	7	20	7.8	10.0	1.0
Oswego	335	71	85	29.64	30.02	−.03	35.4	−3.5	70	3	43	8	30	28	28	32	28	74	3.71	+.3	18	8,159	s.	34	n.	18	2	3	25	8.6	13.1	5.2
Rochester	523	86	102	29.46	30.05	.00	35.0	−3.7	74	3	42	9	27	28	29	31	26	72	2.19	−.4	15	6,872	sw.	32	sw.	17	4	2	24	8.1	9.2	2.0
Syracuse	506	65	79	29.37	30.02	−.04	36.2	−2.5	72	3	44	8	30	29	30				3.80	+1.0	21	6,179	s.	24	nw.	16	3	4	23	8.3	14.3	1.6
Erie	714	130	166	29.28	30.06	.00	37.5	−3.9	70	3	44	8	30	31	26	34	31	80	4.11	+.8	19	10,062	nw.	36	sw.	17	5	6	19	7.7	13.4	2.1
Cleveland	762	267	318	29.24	30.08	+.01	39.0	−1.9	70	3	45	15	30	32	29	34	29	71	3.32	+.7	15	13,165	nw.	45	nw.	15	6	4	20	7.4	14.3	1.4
Sandusky	629	5	67	29.39	30.09	+.01	37.8	−3.3	69	2	45	15	27	30	31				2.20	−.2	10	8,190	sw.	30	sw.	17	7	4	19	6.9	1.1	.0
Toledo	628	79	87	29.41	30.11	+.04	36.8	−3.6	65	2	44	13	27	30	26	33	28	72	1.28	−1.1	8	7,876	w.	30	w.	17	7	6	17	6.7	1.1	.0
Fort Wayne	857	69	84	29.17	30.12		36.8	−3.9	67	2	44	18	30	30	28	33	30	80	3.10	+.2	7	7,568	w.	28	sw.	28	9	5	16	6.1	.2	.0
Detroit [1]	626	5	78	29.38	30.08	+.02	35.4	−3.9	65	3	42	10	27	28	28	31	27	74	1.10	−1.3	9	8,765	sw.	33	sw.	17	7	5	18	7.0	2.0	T
Upper Lake Region							**31.8**	**−3.6**										**76**	**1.22**	**−1.1**										**7.3**		
Alpena	609	13	89	29.35	30.03	+.02	31.2	−3.2	63	3	38	9	30	24	31	28	24	77	1.14	−1.5	14	9,142	nw.	35	nw.	21	2	10	18	7.7	4.4	1.0
Escanaba	612	54	60	29.38	30.06	+.03	29.2	−3.9	59	20	36	9	27	22	33	26	21	75	1.25	−.9	14	8,751	nw.	38	nw.	21	3	6	21	8.0	12.5	3.4
Grand Rapids	707	70	244	29.29	30.08	+.03	36.0	−2.4	67	2	42	12	30	30	30	32	28	75	.43	−2.3	7	9,678	sw.	38	sw.	3	6	6	18	7.2	3.4	.4
Lansing	878	5	90	29.11	30.08		33.6	−3.9	64	2	41	9	30	26	29	30	26	77	.66	−1.8	7	7,667	sw.	28	nw.	15	5	6	19	7.6	.7	.0
Ludington	637	5	54	29.35	30.06		35.2	−2.2	61	3	41	6	30	29	26	31			1.17	−1.5	7		sw.				6	7	17		3.9	1.5
Marquette	734	77	111	29.30	30.04	+.02	28.9	−4.4	57	20	35	10	30	23	23	26	23	83	3.21	+.3	20	8,606	nw.	38	sw.	19	2	5	23	8.4	25.2	17.5
Sault Sainte Marie	614	11	52	29.33	30.05	+.04	25.4	−6.6	60	3	34	−10	30	17	32	23	20	79	2.14	−.5	15	7,086	n.	29	nw.	17	6	4	20	7.4	10.4	7.6
Chicago	673	7	131	29.38	30.12	+.05	38.0	−2.1	68	2	45	18	27	31	30	33	28	70	.90	−1.5	5	8,720	nw.	27	sw.	20	9	7	14	5.8	.6	.0
Green Bay	617	109	141	29.38	30.06	+.02	31.5	−2.5	61	2	39	10	30	24	31	28	22	71	.59	−1.6	3	9,273	sw.	31	w.	14	8	3	19	7.2	1.0	T
Milwaukee	681	97	221	29.33	30.09	+.04	35.5	−1.8	63	2	43	14	27	28	26	31	25	67	.34	−1.4	3	10,727	sw.	36	sw.	2	8	6	16	6.3	.9	T
Duluth	1,133	5	47	28.80	30.07	+.03	23.6	−6.4	52	20	32	1	8	16	30	22	19	81	1.58	+.1	9	10,687	nw.	49	nw.	24	7	6	17	7.0	14.8	1.8
North Dakota							**28.2**	**+1.4**										**80**	**0.38**	**−0.3**										**5.9**		
Moorhead, Minn.	940	50	58	29.10	30.16	+.09	25.2	−1.9	54	20	34	−3	7	16	36	23	20	84	.58	−.3	6	7,315	n.	34	nw.	24	4	10	16	6.9	6.6	T
Bismarck	1,674	8	57	28.33	30.18	+.11	31.2	+2.7	64	19	40	−1	6	22	29	27	23	76	.45	−.1	6	6,756	nw.	35	nw.	20	8	12	10	5.4	6.7	.0
Devils Lake	1,478	11	44	28.52	30.15	+.09	25.6	+1.1	60	19	36	−8	7	15	31	23	20	84	.13	−.6	6	7,189	nw.	42	nw.	20	5	9	16	7.1	2.0	.2
Grand Forks	833	12	67				24.4		58	20	35	−11	7	14	38	21			.32		8		nw.	44	nw.	24	3	14	13		3.2	.6
Williston	1,878	42	50	28.14	30.19	+.13	30.8	+3.6	67	19	41	−11	7	21	32	26	22	75	.38	−.2	4	6,173	w.	36	nw.	20	17	7	6	4.1	4.7	.0
Upper Mississippi Valley							**36.8**	**−1.9**										**73**	**1.37**	**−0.7**										**4.7**		
Minneapolis	919	105	208	29.09	30.10		30.1	−2.3	57	20	38	10	8	22	27	27	22	72	.66	−.6	3	8,767	nw.	38	nw.	20	7	10	13	6.0	1.7	T
La Crosse	714	11	48	29.32	30.11	+.04	32.7	−2.5	62	20	41	12	30	24	29	29	25	76	.86	−.7	3	4,883	nw.	21	nw.	20	10	6	14	5.6	1.6	.0
Madison	974	70	78	29.02	30.11	+.05	33.0	−2.2	61	20	40	11	30	26	25	29	26	78	1.18	−.6	5	7,518	nw.	27	nw.	14	7	6	17	6.4	1.4	.0
Charles City	1,015	10	51	29.03	30.14	+.06	31.4	−1.6	61	20	40	6	8	23	30	28	24	79	1.35	−.2	6	5,657	nw.	23	nw.	24	11	10	9	5.2	3.4	T
Davenport	606	66	161	29.47	30.15	+.07	37.4	−1.6	67	1	46	17	27	29	28	32	27	72	1.64	−.2	5	8,108	nw.	33	nw.	20	11	11	8	5.2	.3	.0
Des Moines	861	5	99	29.24	30.17	+.09	36.6	−1.8	72	1	46	12	8	27	39	31	27	73	.76	−.7	5	7,710	nw.	31	nw.	24	11	12	7	4.3	1.4	.0
Dubuque	699	60	79	29.36	30.14	+.07	34.8	−2.2	64	20	43	15	30	26	28	30	26	74	.69	−1.0	6	5,271	nw.	27	nw.	20	9	11	10	5.4	2.9	.0
Keokuk	614	64	78	29.50	30.18	+.09	39.3	−1.8	74	1	49	13	27	30	32	33	27	66	.84	−1.1	3	6,358	sw.	24	w.	2	15	7	8	4.0	.5	.0
Cairo	358	87	93	29.80	30.20	+.08	44.6	−2.7	79	2	54	20	27	35	33	38	32	68	2.78	−.9	5	6,548	n.	26	s.	2	17	5	8	4.1	4.3	.0
Peoria	609	11	45	29.48	30.16	+.07	37.8	+.3	68	1	47	15	27	29	30	33	29	77	1.18	−1.2	3	5,749	s.	21	nw.	14	15	8	7	4.1	.1	.0
Springfield, Ill.	636	5	191	29.48	30.17	+.07	40.0	−2.2	69	1	48	15	27	32	30	34	29	71	2.30	−.2	2	8,720	nw.	34	nw.	21	15	8	7	4.1	.8	.0
St. Louis	568	179	303	29.56	30.18	+.08	43.4	−2.0	72	20	53	19	27	34	32	36	30	65	2.20	−.6	2	8,965	nw.	44	sw.	2	23	2	5	2.5	1.1	.0
Missouri Valley							**38.4**	**−0.9**										**67**	**0.56**	**−0.8**										**3.4**		
Columbia, Mo.	784	6	84	29.33	30.19	+.10	40.8	−2.5	76	1	51	14	27	30	37				1.48	−.7	2	6,390	sw.	27	n.	24	19	5	6	3.2	2.8	.0
Kansas City [1]	750	32	45	29.38	30.21	+.12	42.4	−1.3	79	1	55	20	3	30	48	35	28	62	.19	−1.6	2	7,893	sw.	36	n.	26	19	7	4	3.1	T	.0
St. Joseph	967	11	49	29.13	30.20		41.2		77	1	53	17	8	30	43	33	26	62	.04	−1.6	3	6,908	nw.	30	nw.	24	20	7	3	2.4	T	.0
Springfield, Mo.	1,324	98	104	28.77	30.21	+.11	43.0	−2.7	75	1	53	22	27	33	36	37	30	62	1.38	−1.4	1	7,170	nw.	30	nw.	26	21	5	4	2.8	T	.0
Topeka	987	65	87	29.13	30.21		43.1	+.3	78	1	56	16	8	30	43	35	27	60	.09	−1.4	1	6,973	nw.	30	n.	26	20	7	3	2.1	T	.0
Lincoln	1,189	11	81	28.89	30.20	+.12	39.8	+.7	75	20	52	11	8	28	38	32	24	60	.06	−1.0	2	8,111	nw.	37	nw.	24	15	10	5	3.4	T	.0
Omaha [1]	982	31	44	29.11	30.19	+.11	37.6	−.9	70	20	50	10	8	26	39	31	25	66	.14	−.9	2	8,256	nw.	36	nw.	24	15	8	7	3.8	.1	.0
Valentine	2,598	47	54	27.45	30.26	+.18	32.9	−1.7	64	19	44	−4	7	22	39	27	23	76	.83	+.3	7	6,734	w.	34	n.	24	11	9	10	4.7	10.4	.0
Sioux City	1,138	64	106	28.92	30.18	+.10	35.8	+.6	68	19	46	8	8	26	38	31	25	70	.34	−.7	4	7,524	nw.	40	nw.	24	14	7	9	4.3	2.3	.0
Huron	1,307	59	74	28.75	30.20	+.12	30.6	−.9	60	19	39	2	8	22	36	27	24	81	1.05	+.5	5	7,112	nw.	37	nw.	24	17	4	9	4.4	9.8	.0
Northern Slope							**32.3**	**−0.4**										**69**	**0.33**	**−0.4**										**4.4**		
Havre	2,505	11	67	27.54	30.26	+.23	34.8	+3.6	74	19	47	−16	7	23	49	28	21	64	.23	−.4	4	8,316	sw.	41	sw.	19	15	10	5	3.8	3.2	.0
Helena	4,124	85	111	26.07	30.44	+.34	27.8	−5.4	53	21	36	−4	7	19	27	24	20	76	.39	−.4	7	3,376	sw.	23	sw.	17	8	8	14	5.8	8.0	.3
Missoula	3,263	80	91				30.6	−2.9	58	20	40	9	2	22	26				.13	−1.1	5	3,818	se.	30	e.	1	12	5	13	5.4	1.5	T
Kalispell	2,973	48	56	27.24	30.44	+.37	25.1	−7.2	50	20	32	1	2	18	25	24	22	89	.42	−.9	6	3,116	w.	18	n.	5	11	3	16	6.1	7.2	.3
Miles City	2,371	48	55	27.66	30.30	+.23	34.6	+3.7	71	19	45	−4	3	24	38	30	24	69	.37	−.2	4	4,877	s.	38	nw.	22	13	7	10	4.8	7.1	.0
Rapid City	3,259	50	58	26.77	30.28	+.20	37.6	+1.7	75	19	50	5	3	26	42	31	24	65	.69	+.2	4	5,994	nw.	38	nw.	22	14	11	5	4.0	8.3	.0
Cheyenne [1]	6,088	5	44	24.08	30.27	+.20	35.4	+.6	65	14	49	5	3	22	39	27	19	58	.24	−.3	6	9,923	nw.	44	nw.	22	15	12	3	3.3	2.3	T
Lander	5,372	60	68	24.83	30.36	+.26	32.0	+1.7	63	16	45	−5	3	19	40	26	21	70	.35	−.2	4	2,903	sw.	16	ne.	22	19	7	4	3.1	4.4	.5
Sheridan	3,790	10	47	26.29	30.32		34.3		73	19	49	1	3	20	46	27	22	70	.38	−.2	6	3,770	nw.	30	nw.	25	16	6	8	4.2	4.6	.0
Yellowstone Park	6,241	12	46	24.10	30.50	+.39	26.8	−2.3	54	14	38	−7	3	15	30	21	15	67	.40	−.3	4	4,632	sw.	20	sw.	5	13	9	8	4.4	7.1	.3
North Platte	2,821	11	51	27.23	30.25	+.17	38.6	+2.0	68	19	54	7	3	24	43	29	22	64	.03	−.4	1	6,147	w.	33	n.	24	16	9	5	3.5	.3	.0

[1] Observations taken at airport.

TABLE 1.—*Climatological data for Weather Bureau stations, November 1936*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to means of 24 hours	Pressure: Sea level, reduced to means of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Middle Slope							43.5	+0.7										55	0.10	−0.9										2.6		
Denver	5,292	106	113	24.88	30.25	+0.19	41.8	+2.0	70	13	54	4	3	29	36	32	21	50	0.30	−0.2	4	5,687	s.	26	nw.	22	22	4	4	2.8	3.7	0.0
Pueblo	4,685	80	86	25.46	30.24	+.19	41.7	+2.3	74	22	58	11	3	25	48	31	21	53	.21	−.2	2	4,480	nw.	29	w.	16	22	4	4	2.4	2.2	.0
Concordia	1,392	50	58	28.73	30.25	+.17	41.7	+.3	75	20	54	15	8	29	38	33	25	60	T	−1.0	0	6,817	n.	35	nw.	25	17	9	4	3.0	T	.0
Dodge City	2,509	10	86	27.59	30.25	+.18	43.4	+.8	75	20	58	15	3	29	42	33	23	54	T	−.7	0	8,348	n.	33	nw.	23	25	2	3	2.0	T	.0
Wichita	1,358	85	93	28.76	30.22	+.14	44.8	.0	76	1	57	19	8	33	46	36	26	54	.01	−1.4	1	7,816	sw.	34	sw.	2	21	6	3	2.2	T	.0
Oklahoma City	1,214	10	47	28.92	30.23	+.15	47.6	−1.2	80	2	58	23	4	37	50	39	31	60	.06	−1.8	2	6,975	s.	27	nw.	2	19	4	7	3.1	.0	.0
Southern Slope							49.9	−1.9										58	0.36	−0.7										4.4		
Abilene	1,738	10	52	28.40	30.25	+.18	50.6	−2.9	82	2	62	26	4	40	39	43	37	67	.62	−.7	4	5,584	s.	24	n.	23	12	9	9	5.0	.0	.0
Amarillo	3,676	10	49	26.45	30.24	+.19	46.5	+1.0	74	20	60	18	3	33	38	34	22	45	T	−.9	0	6,678	sw.	32	w.	2	24	3	3	2.1	.0	.0
Del Rio	960	63	71	29.18	30.18	+.13	56.6	−3.4	86	2	66	35	4	47	36	49	44	69	.55	−.7	7	5,355	nw.	27	nw.	3	3	9	18	7.3	.0	.0
Roswell	3,566	75	85	26.55	30.23	+.20	45.8	−2.3	77	1	60	20	4	31	43	36	25	52	.28	−.6	4	5,034	s.	29	ne.	23	16	8	6	3.2	T	.0
Southern Plateau							49.3	+0.9										50	0.35	−0.1										2.7		
El Paso	3,778	82	101	26.34	30.18	+.18	50.6	−2.1	81	7	61	26	4	40	35	41	31	53	1.32	+.8	8	5,593	e.	24	n.	3	18	4	8	3.9	T	.0
Albuquerque	4,972	5	39	25.21	30.22	------	42.0	−1.3	71	15	58	17	4	25	43	31	21	51	T	−.5	0	5,474	n.	34	w.	2	22	5	3	2.1	.0	.0
Santa Fe	7,013	38	53	23.38	30.23	+.20	39.6	+.7	65	14	52	15	3	27	32	30	21	56	T	−.7	0	3,783	n.	21	w.	2	23	6	1	3.0	T	.0
Flagstaff	6,907	10	59	23.52	30.14	+.12	37.8	+3.2	66	15	52	15	3	24	43	30	----	62	.43	------	2	6,264	e.	32	n.	18	17	8	5	----	T	.0
Phoenix	1,108	10	107	28.90	30.06	+.08	61.8	+2.1	87	15	76	38	5	48	42	48	34	42	.35	−.4	4	3,668	e.	22	ne	19	18	9	3	2.7	.0	.0
Yuma	141	9	54	29.92	30.07	+.09	63.8	+1.4	86	15	77	40	6	51	37	49	33	39	.42	+.1	5	4,973	n.	24	n.	18	23	6	1	1.9	.0	.0
Independence	3,957	5	26	26.14	30.22	+.17	49.5	+2.3	75	17	65	26	29	34	40	36	18	----	.00	−.3	0	------	n.	----	----	----	27	3	0	----	.0	.0
Middle Plateau							38.1	−1.3										56	0.27	−0.5										1.7		
Reno	4,527	61	76	25.68	30.31	+.20	41.8	+.3	69	11	58	19	3	25	42	32	21	49	.03	−.6	2	3,205	sw.	18	ne.	6	24	5	1	1.3	.2	.0
Tonopah	6,090	12	20	------	------	------	43.6	------	62	16	52	20	3	35	23	32	17	35	.08	------	1	------	nw.	----	----	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.86	30.36	+.22	36.8	−1.6	68	15	57	8	29	16	52	27	16	50	T	−.7	0	4,839	ne.	16	n.	6	23	5	2	1.9	T	.0
Modena	5,473	10	43	24.79	30.26	+.18	36.6	+.2	67	16	52	15	9	21	44	28	21	63	.05	−.5	1	5,492	w.	26	nw.	1	26	3	1	1.3	.1	.0
Salt Lake City [1]	4,227	32	46	25.98	30.36	+.24	36.2	−4.9	57	17	48	6	3	24	30	30	27	81	.99	−.4	2	4,340	se.	23	nw.	2	22	4	4	2.5	6.5	.0
Grand Junction	4,602	60	68	25.60	30.26	+.18	39.0	−.3	63	14	53	18	30	25	34	31	22	55	.21	−.4	2	3,798	se.	24	sw.	1	24	5	1	1.4	.8	.0
Northern Plateau							35.2	−3.7										62	0.03	−1.3										4.2		
Baker	3,471	48	53	26.74	30.43	+.27	34.2	−1.8	61	14	49	10	29	19	38	27	17	54	T	−1.0	0	4,666	se.	18	nw.	1	16	7	7	3.8	.1	.0
Boise	2,739	79	87	27.48	30.43	+.26	37.4	−3.6	59	17	49	18	2	26	29	30	21	52	.01	−1.3	1	2,853	se.	19	n.	1	18	9	3	3.2	T	.0
Pocatello	4,477	60	68	25.72	30.38	+.24	35.8	−.9	61	21	49	12	3	22	37	28	21	61	.09	−.8	4	4,439	se.	21	sw.	17	19	8	3	3.0	.8	T
Spokane	1,929	101	110	28.30	30.43	+.33	32.3	−6.2	60	19	41	10	2	23	33	29	24	74	.08	−2.0	1	3,034	n.	16	n.	1	12	8	10	5.0	T	.0
Walla Walla	991	57	65	29.30	30.41	+.28	36.2	−6.6	66	17	44	19	27	28	27	32	25	65	.01	−2.0	1	2,749	s.	15	s.	3	13	8	9	4.8	.0	.0
Yakima	1,076	58	67	29.22	30.41	------	35.6	−3.3	60	22	46	17	10	25	32	31	24	64	T	−.8	0	2,477	se.	12	n.	20	13	6	11	5.1	T	T
North Pacific Coast Region							46.3	−0.2										75	0.94	−5.5										5.0		
North Head	211	11	56	30.05	30.28	+.23	50.5	+2.3	69	24	57	35	30	44	23	46	41	78	1.12	−7.3	7	6,569	e.	37	se.	16	15	8	7	4.2	.0	.0
Seattle	125	90	321	30.17	30.30	+.26	46.0	+.4	67	18	53	28	2	39	23	43	40	79	1.05	−4.0	4	5,175	se.	29	sw.	3	5	12	13	6.3	.0	.0
Tatoosh Island	86	10	54	30.18	30.28	+.31	47.3	+1.4	68	24	51	37	2	44	21	45	42	84	2.85	−9.1	9	11,748	e.	47	e.	24	9	6	15	6.0	.0	.0
Medford [1]	1,329	29	58	28.83	30.28	------	43.1	------	71	23	60	15	30	26	46	35	25	56	.01	−2.5	1	------	nw.	----	----	----	19	6	5	2.8	.0	.0
Portland, Oreg	153	68	106	30.13	30.29	+.19	45.6	−1.3	64	20	53	30	2	38	23	41	37	74	.36	−5.7	3	3,615	nw.	15	e.	28	14	10	6	4.3	.0	.0
Roseburg	510	45	76	29.72	30.29	+.17	42.0	−3.9	69	3	52	24	11	32	35	39	36	81	.25	−4.4	3	2,102	n.	11	nw.	17	4	11	15	6.4	.0	.0
Middle Pacific Coast Region							55.7	+1.9										60	0.01	−3.4										3.3		
Eureka	62	73	89	30.15	30.22	+.11	48.6	−2.5	70	13	55	34	30	42	27	46	44	85	.01	−5.2	1	3,174	e.	21	n.	6	9	6	15	6.3	.0	.0
Redding [1]	722	20	34	------	------	------	61.1	+7.0	92	19	74	38	4	48	39	45	24	28	T	−4.4	0	5,439	nw.	24	n.	30	21	7	2	2.0	.0	.0
Sacramento	66	92	115	30.08	30.15	+.06	55.0	+1.4	76	19	69	31	30	41	37	46	36	55	.03	−1.8	1	3,636	n.	25	n.	30	27	2	1	1.4	.0	.0
San Francisco	155	112	132	29.97	30.14	+.05	58.0	+1.7	78	13	66	45	27	50	25	50	44	70	.01	−2.3	1	3,887	w.	21	ne.	30	12	14	4	3.6	.0	.0
South Pacific Coast Region							62.6	+4.4										53	0.16	−0.8										2.7		
Fresno	327	97	105	29.79	30.15	+.09	56.4	+2.2	80	20	69	33	30	44	31	50	44	66	T	−.9	0	2,989	nw.	14	w.	1	23	4	3	1.8	.0	.0
Los Angeles	338	159	191	29.70	30.07	+.05	67.8	+6.9	90	15	78	49	3	57	29	51	36	38	.05	−1.2	1	4,174	ne.	22	ne.	21	18	11	1	2.2	.0	.0
San Diego	87	62	70	29.95	30.04	+.02	63.7	+4.0	83	14	73	48	4	54	27	53	43	54	.44	−.3	3	4,032	nw.	21	s.	22	16	5	9	4.0	.0	.0
West Indies																																
San Juan, P. R	82	9	54	29.86	29.94	------	77.8	−.6	84	15	82	70	2	73	12	----	----	----	5.55	−1.2	18	7,610	e.	36	e.	2	9	19	2	4.2	.0	.0
Panama Canal																																
Balboa Heights	118	6	97	------	------	------	------	------	----	----	----	----	----	----	----	----	----	----	------	------	----	------	----	----	----	----	----	----	----	----	----	----
Cristobal	36	6	97	------	------	------	------	------	----	----	----	----	----	----	----	----	----	----	------	------	----	------	----	----	----	----	----	----	----	----	----	----
Alaska																																
Fairbanks	454	11	87	29.25	29.80	------	10.8	------	54	25	18	−29	16	3	46	----	----	81	1.88	------	12	3,432	ne.	26	sw.	26	3	8	19	----	19.9	9.5
Juneau	80	96	116	[2] 29.85	[2] 29.94	------	42.2	------	54	24	46	30	5	39	15	40	38	84	25.87	------	28	6,849	s.	31	se.	17	0	3	27	9.7	8.2	.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.95	[2] 29.99	------	74.8	+.3	83	12	79	63	26	71	14	67	63	69	1.69	−2.2	9	7,049	e.	30	ne.	18	13	10	7	4.9	.0	.0

[1] Observations taken at airport.
[2] Pressure not reduced to mean 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, November 1936*

Station	Altitude above mean sea level, Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	In.	In.	In.	°F.	°F.	°F.	°F.	°F.	°F.	In.	In.	In.
Cape Race, Newfoundland	99												
Sydney, Cape Breton Island	48												
Halifax, Nova Scotia	88												
Yarmouth, Nova Scotia	65												
Charlottetown, Prince Edward Island	38												
Chatham, New Brunswick	28												
Father Point, Quebec	20												
Quebec, Quebec	296												
Doucet, Quebec	1,236				13.8		23.3	4.4	59	−32	3.95		31.6
Montreal, Quebec	187												
Ottawa, Ontario	236												
Kingston, Ontario	285	29.68	30.00	−0.04	33.1	−1.9	40.4	25.8	60	−2	3.16	−0.08	10.2
Toronto, Ontario	379	29.61	30.03	−.01	34.3	−1.3	41.2	27.4	64	3	1.30	−1.84	4.8
Cochrane, Ontario	930				12.8		22.4	3.2	48	−25	4.39		39.2
White River, Ontario	1,244												
London, Ontario	808												
Southampton, Ontario	656	29.29	30.02	.00	31.2	−3.8	37.9	24.5	66	1	2.64	−1.06	18.3
Parry Sound, Ontario	688												
Port Arthur, Ontario	644												
Winnipeg, Manitoba	760												
Minnedosa, Manitoba	1,690												
Le Pas, Manitoba	860												
Qu'Appelle, Saskatchewan	2,115	27.78	30.10	+.10	27.6	+8.8	37.0	18.1	66	−11	.29	−.60	2.8
Moose Jaw, Saskatchewan	1,759												
Swift Current, Saskatchewan	2,392	27.53	30.13	+.11	30.7	+7.5	40.8	20.6	72	−7	.24	−.45	2.4
Medicine Hat, Alberta	2,365	27.65	30.19	+.19	33.4	+6.0	44.7	22.2	74	−10	.29	−.63	2.7
Calgary, Alberta	3,540	26.45	30.20	+.22	36.7	+10.9	48.2	25.1	70	−12	.14	−.74	1.3
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450	28.52	30.15	+.12	26.2	+10.8	33.9	18.6	55	−9	.46	−.37	4.2
Battleford, Saskatchewan	1,592												
Edmonton, Alberta	2,150	27.79	30.14	+.17	31.3	+8.4	39.8	22.8	59	−11	.98	+.40	8.3
Kamloops, British Columbia	1,262	29.06	30.40	+.44	34.3	+.9	38.8	29.7	63	13	.40	−1.06	.5
Victoria, British Columbia	230	30.05	30.31	+.32	44.6	+1.4	49.1	40.2	56	34	1.25	−5.72	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20				45.4		51.2	39.6	58	31	9.06		.0
Prince Rupert, British Columbia	170												
St. Georges, Bermuda	158		30.10	+.05	69.9	+1.7	74.6	65.2	83	56	4.84	−.07	.0

LATE REPORTS, OCTOBER 1936

Station	Altitude	Station pressure	Sea level	Departure	Mean	Departure	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure	Total snowfall
Montreal, Quebec	187	29.80	30.01	0.00	45.6	+0.8	52.3	39.0	73	20	6.75	+3.62	2.7
Kingston, Ontario	285	29.71	30.02	−.01	48.0	+1.0	55.2	40.8	67	19	4.32	+1.59	T
Cochrane, Ontario	930				32.3		39.2	25.3	65	6	3.94		19.5
London, Ontario	808				47.2		56.0	38.4	72	20	3.56		T
Parry Sound, Ontario	688	29.30	30.00	−.01	44.4	+.5	52.2	36.6	70	15	4.34	+.42	2.0
Minnedosa, Manitoba	1,690	28.16	30.02	+.05	35.5	−2.3	46.4	24.6	78	−4	.67	−.53	6.7
Prince Rupert, British Columbia	170				49.2		54.3	44.0	67	30	11.89		.0

TABLE 3.—*Severe local storms, November 1936*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Cape Girardeau, Mo.	2				$75,000	Wind; probable tornado.	Property damaged; 1 person injured.
San Diego County, Calif.[1]	3	9-10 p.m.				Gale	Wind of 70 miles an hour recorded. All phone lines out of Julian, Warner Spring, and Mesa Grande interrupted. At Witch Creek power lines were broken. Shingles torn from roofs at Jacumba. The Pine Valley district was one of the sections most affected. The terrific gale tore the C. C. C. camp pump-house from its foundation and carried a heavy gasoline engine more than 75 feet. Throughout the mountain district trees were stripped of branches and uprooted. Cuyama, Campo, and Buckman Springs also received the full force of the gale.
Evansville, Ind.	3-4					Rain, sleet, and glaze.	Glaze formed on streets, walks, trees, poles, and other exposed surfaces Trees and shrubbery damaged by the accumulation of the moist snow on the 4th.
Cincinnati, Ohio[1]	4					Snow	An all-day driving snowstorm swept through this area today leaving a record early season fall of 9 inches. Traffic, telegraph, and light service disrupted.
New York State, northern portion.	4-5			1		do	Considerable damage to telephone and power lines. In Buffalo 9.2 inches of snow fell. In Canandaigua a man was killed when a truck and trailer he was driving skidded. Several motorists injured during the blinding snowstorm that piled up 4 inches of heavy snow on the level.

[1] From press reports

TABLE 3.—*Severe local storms, November 1936*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Havre, Mont	19					Wind and dust	The region of the horizon was a grayish tan and visibility reduced to 1.2 miles for about an hour because of dust. A large cottonwood tree was blown down; minor damage to insecure fences.
Minnesota	20					Dust	This severe duststorm caused some injury to winter wheat.
Colorado, eastern section	22–24					Wind and dust	Visibility reduced to ½ mile at intervals. The air was dust-laden over most of the eastern prairie lands area of Colorado during this entire period.
Minnesota, extreme west-central counties.	24					Wind	Damage to farm buildings.
Omaha, Nebr	24–25	Noon 24th 1 a. m. 25th.				Wind and dust	Most disagreeable duststorm in many months. Visibility as low as 4 miles.
Muskegon, Mich.[1]	25					Gale	A gravel boat went aground with a crew of 27 aboard.
Concordia, Kans	25–26	P. m.				Wind and dust	Dust blown with the wind reducing visibility about 220 yards at the beginning of the storm. Damage to wheat.
La Porte, Ind., and vicinity	26					Snow	14 inches of snow reported. Low visibility and slippery roads resulted in traffic accidents causing injuries to 16 persons.
Cuyahoga County, Ohio	26					Heavy snow	Storm confined almost entirely to that portion of this county near and along Lake Erie. 11.6 inches of snow recorded.
Grand Rapids, Mich	27					Snow and wind	Streets and walks icy and slippery. Minor damage reported.
Buffalo, N. Y., and vicinity	28			*2		do	Number of automobile and traffic accidents reported. Some freighters held in port. Deaths due to traffic accidents.
Grand Rapids, Mich	29			1		Snow	Motor transportation and walking extremely hazardous. Several pedestrians injured.

[1] From press reports.
* See adjoining "remarks" for qualifying statement.

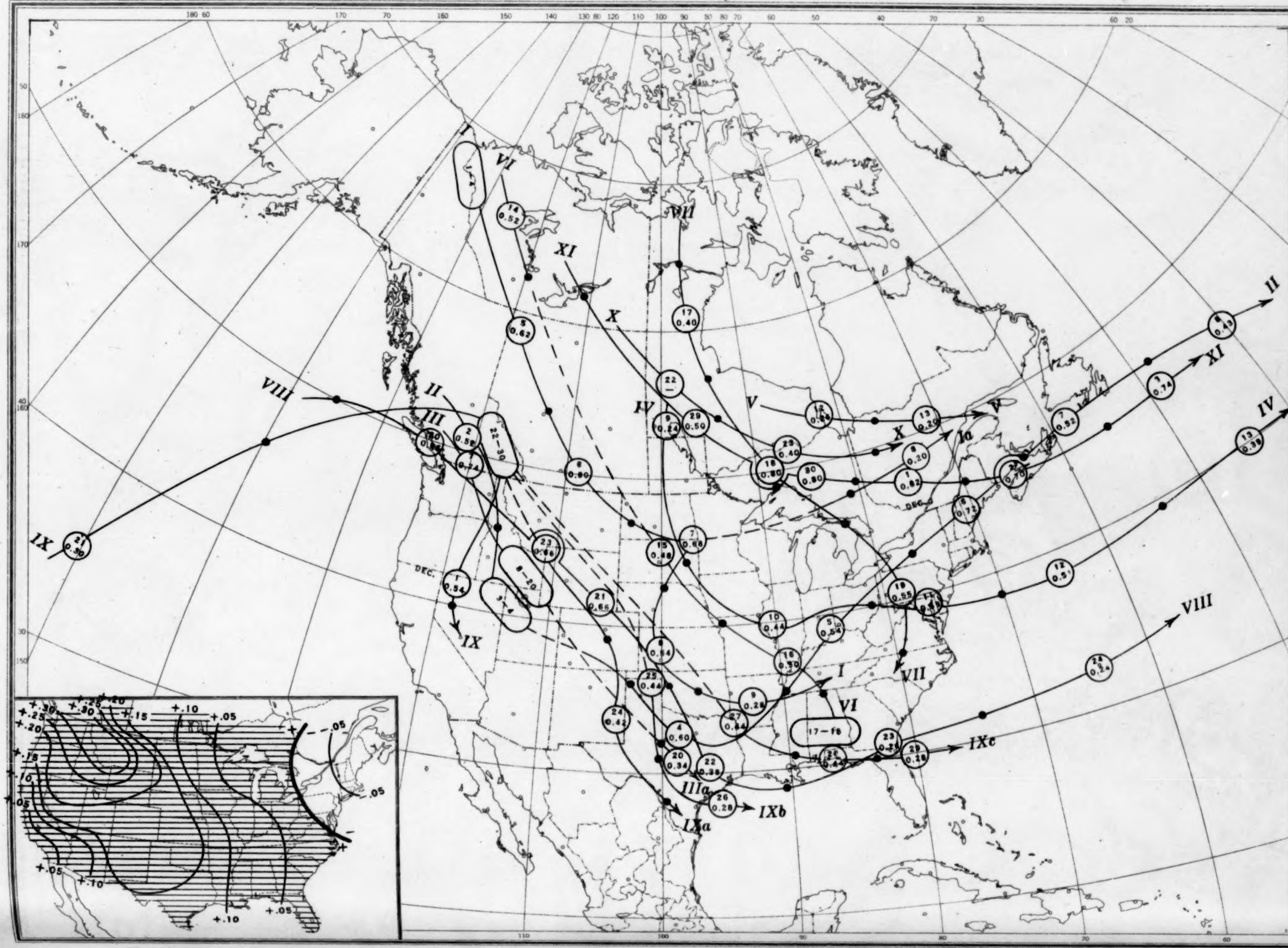
U. S. GOVERNMENT PRINTING OFFICE: 1937

Chart I. Departure (°F.) of the Mean Temperature from the Normal, November 1936

Chart I. Departure (°F.) of the Mean Temperature from the Normal, November 1936

Chart II. Tracks of Centers of Anticyclones, November 1936. (Inset) Departure of Monthly Mean Pressure from Normal

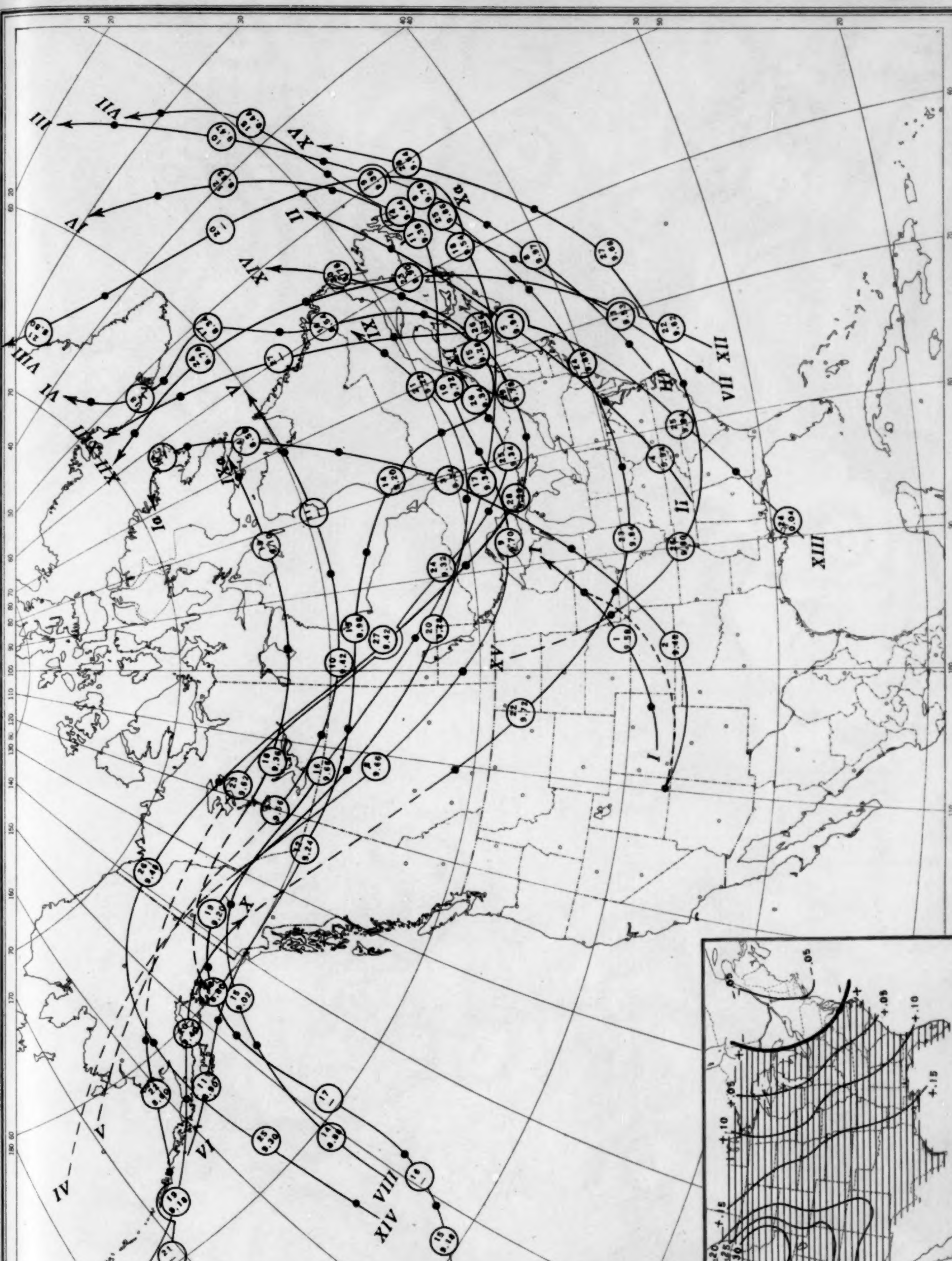
(Plotted by W. P. Day)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, November 1936. (Inset) Change in Mean Pressure from Preceding Month

Chart III. Tracks of Centers of Cyclones, November 1936. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by W. P. Day)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, November 1936

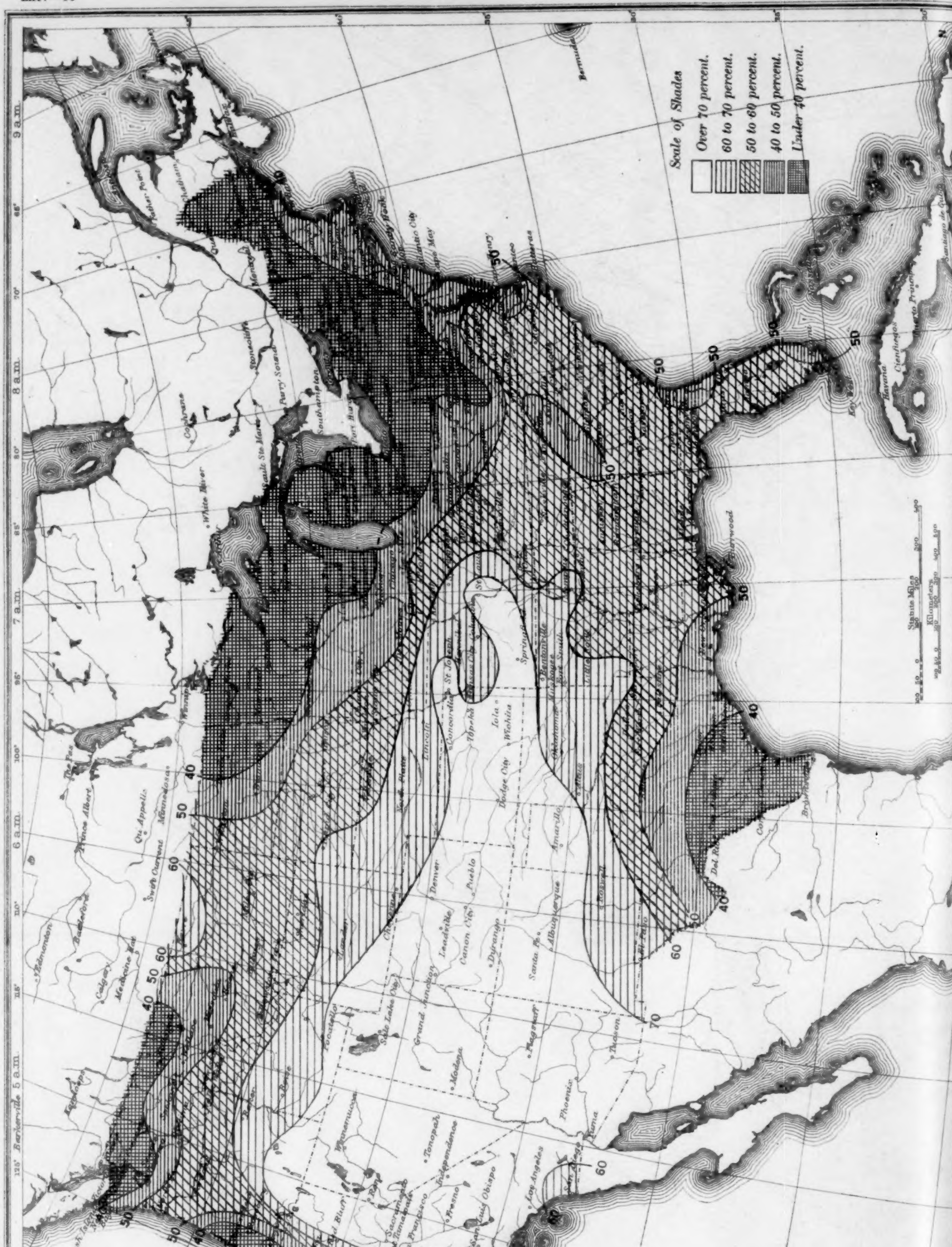


Chart V. Total Precipitation, Inches, November 1936. (Inset) Departure of Precipitation from Normal

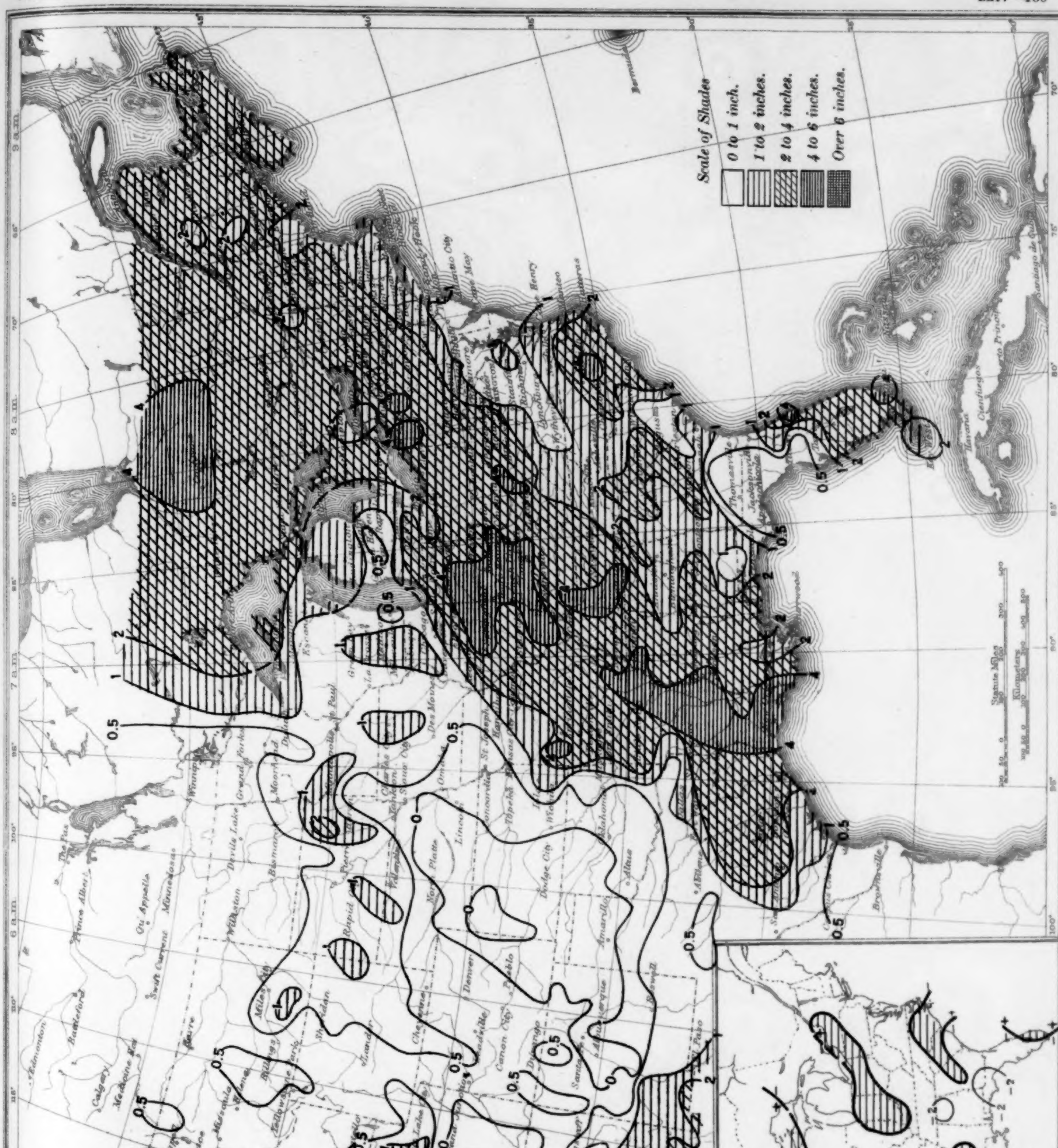
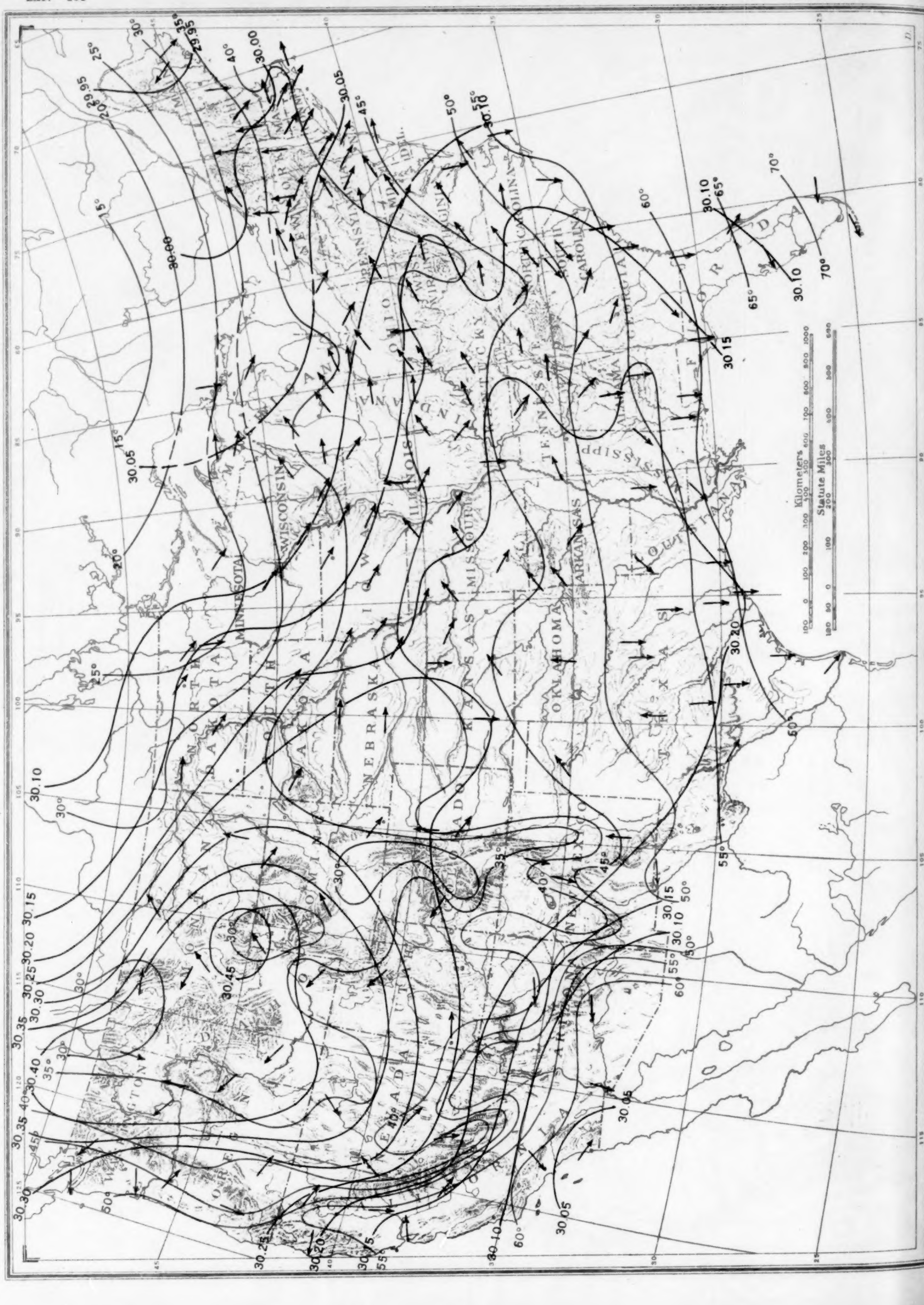


Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, November 1936



(Plotted by W. W. Reed)

Chart VIII. Total Snowfall, Inches, November 1936.

Chart IX. Weather Map of North Atlantic Ocean, November 13, 1936
(Plotted from the Weather Bureau Northern Hemisphere Chart.)

Chart IX. Weather Map of North Atlantic Ocean, November 13, 1936
(Plotted from the Weather Bureau Northern Hemisphere Chart)

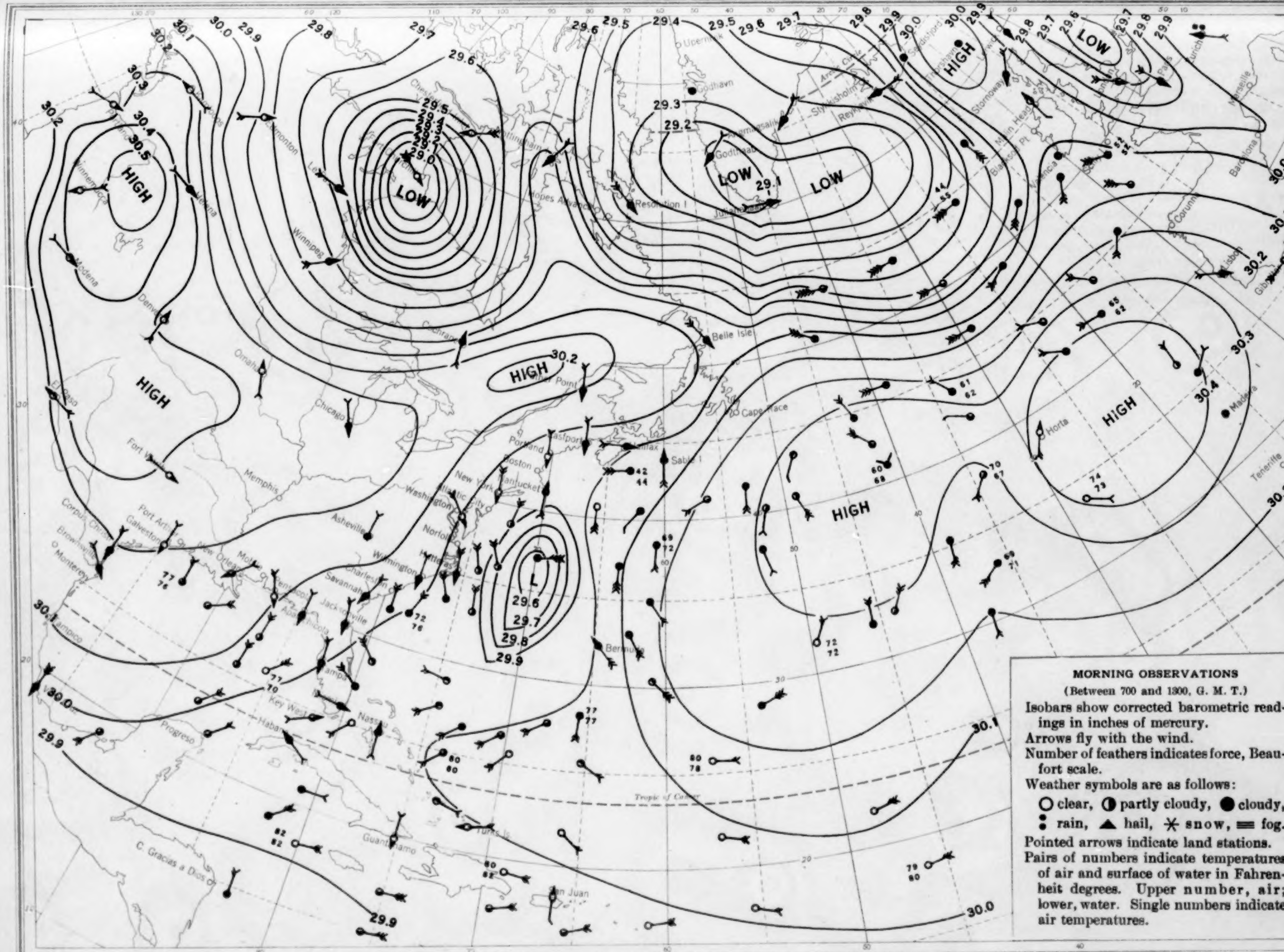


Chart X. Weather Map of North Atlantic Ocean, November 23, 1936

(Plotted from the Weather Bureau Northern Hemisphere Chart)